NNSA National Nuclear Security Administration

Department of Energy
National Nuclear Security Administration
Washington, DC 20585

July 18, 2006

The Honorable A.J. Eggenberger
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, N.W., Suite 700
Washington, D.C. 20004-2901

Dear Mr. Chairman:

On July 1, 2003, you sent a letter to the Administrator concerning site-wide lightning protection and detection issues at the Nevada Test Site (NTS). The Board also requested to be kept abreast of National Nuclear Security Administration (NNSA) actions regarding the concerns.

On May 14, 2004, the Administrator forwarded a response from the Nevada Site Office (NSO) addressing the Board's issues. In its response, NSO also committed to (1) developing a site-wide policy on lightning safety and (2) conducting a study of the effectiveness of lightning detection systems at the NTS. As requested by the Board, the enclosed submittal from NSO provides the results of these actions.

If you have any questions, please contact Xavier Ascanio at (301) 903-3757 or Jay Norman, NSO Manager, at (702) 295-3211.

Sincerely,

Thomas P. D'Agostino
Deputy Administrator
for Defense Programs

Enclosure

cc; w/ enclosure:
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J. Norman, NSO
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Department of Energy
National Nuclear Security Administration
Nevada Site Office
P.O. Box 98518
Las Vegas, NV 89193-8518

MAY 24 2006

Thomas P. D'Agostino, Deputy Administrator for Defense Programs, NNSA/HQ (NA-10) FORS

SITE-WIDE LIGHTNING PROTECTION AND DETECTION AT THE NEVADA TEST SITE (NTS)

This letter is to inform you that we have completed the site-wide lightning protection and detection actions that we committed to in the enclosed April 15, 2004, response to the July 1, 2003, letter from the Defense Nuclear Facilities Safety Board Chairman to the Administrator, National Nuclear Security Administration (NNSA). Specific actions include the following:

1. A Site-Wide Lightning Detection and Protection Order (NSO O 440.X2) has been developed, approved, and included in the NNSA Nevada Site Office's (NNSA/NSO) Work Smart Standards. The Order is enclosed for your information and use.

2. A study of range applicable lightning detection systems has been completed and was reviewed and accepted by the NNSA/NSO Lightning Focus Group (LFG). As a result of this study, the LFG concluded that the existing lightning detection system used at the Nevada Test Site (NTS) provides the information necessary for safe operations at the NTS. The study results were briefed to the NNSA/NSO Executive Council on January 30, 2006, and the Executive Council concurred with the LFG recommendation. The report is enclosed for your information and use.

3. An analysis of thunderstorm forecasts and cloud-to-ground lightning in the vicinity of the NTS has been completed providing the technical basis for lightning alert distances at the NTS. This report was also reviewed and accepted by the LFG and is enclosed for your information and use.

If you have any questions, please contact me at (702) 295-3211 or Kevin D. Thornton, of my staff, at (702) 295-1541.

Jay H. Norman
Acting Manager

IPT:KDT-6109

Enclosures:
As stated

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U.S. DEPARTMENT OF ENERGY
NATIONAL NUCLEAR SECURITY ADMINISTRATION
NEVADA SITE OFFICE

ORDER

NSO O 440.X2

Approved: 11-22-05
Review Date: 11-22-07
Expires: 11-22-09

SITE-WIDE LIGHTNING DETECTION AND PROTECTION

National Nuclear Security Administration

INITIATED BY:
Office of the Assistant Manager for Site Operations

1. OBJECTIVE. To establish the requirements for site-wide lightning detection and protection at the National Nuclear Security Administration (NNSA) Nevada Site Office (NNSA/NSO) Nevada Test Site (NTS) to protect property and guard the safety of NTS personnel.

2. CANCELLATION. None.

3. APPLICABILITY.

    a. The provisions of this Order apply to all NNSA/NSO organizational elements including contractors, National Laboratories, other federal agencies, and other user organizations performing work under the purview of NNSA/NSO.

    b. Contractor requirements are contained in the Contractor Requirements Document (CRD), Attachment 1. Compliance with the CRD is required to the extent set forth in an NNSA contract.

4. REQUIREMENTS.

    a. The Air Resources Laboratory/Special Operations and Research Division (ARL/SORD) will maintain the capability to provide NTS weather forecasts.

    b. ARL/SORD will maintain the capability to detect lightning within 20 miles of the NTS boundary.

    c. ARL/SORD will notify the Operations Coordination Center when lightning has been detected within 20 miles of the NTS boundary.

    d. The Operations Coordination Center will maintain the capability for site-wide notification of hazardous weather conditions.

    e. The Operations Coordination Center will maintain a Hazardous Weather Notification List which identifies specific facilities and project activities meeting the following criteria:

        (1) Facilities or activities that involve the handling of energetic materials.

        (2) Hazardous Category II and III nonreactor nuclear facilities.

(3) Facilities or activities where personnel may (routinely) be exposed to lightning during the normal course of their duties.

f. The Operations Coordination Center will maintain the capability to provide live voice communication of hazardous weather conditions to specific facilities and project activities on the Hazardous Weather Notification List.

g. Facility Managers/Project Managers will establish lightning procedures specific to their facilities and project activities identified on the Hazardous Weather Notification List that include:

(1) Establishment of a lightning proximity threshold boundary (minimum 10 miles) that allows sufficient time to halt work and place personnel and vulnerable assets or assemblies in a lightning safe configuration.

(2) Lines of communication for live voice notification of the Facility Manager or designee of lightning within the established lightning proximity threshold.

(3) Requirements to verify current and forecast weather conditions with ARL/SORD prior to the start of facility or project activities unacceptably impacted by potential lightning hazards.

(4) Lightning protection procedures and controls for notifying and protecting both personnel and vulnerable assets including specific criteria for terminating a lightning alert.

5. RESPONSIBILITES.

a. Assistant Managers. Ensure facilities and project activities under their purview that meet the criteria in 4e above are included on the Hazardous Weather Notification List and that lightning procedures specific to those facilities and project activities are established.

b. Assistant Manager for Site Operations (AMSO).

(1) Provides oversight and direction to the Operations Coordination Center for maintaining the capability to provide site-wide Hazardous Weather Notifications.

(2) Provides oversight and direction to the Operations Coordination Center for maintaining the Hazardous Weather Notification List and providing live-voice notification for facilities and project activities included on the Hazardous Weather Notification List.

c. Assistant Manager for National Security. Provides oversight and direction to ARL/SORD for maintaining lightning detection capabilities, providing weather forecasts, and notifying the Operations Coordination Center of hazardous weather conditions.

6. REFERENCES. SORD Technical Memorandum, SORD-2005-01, *Analysis of Thunderstorm Forecasts and Cloud-to-Ground Lightning in the Vicinity of the Nevada Test Site.*

7. CONTACT. Questions concerning this Order should be addressed to AMSO at (702) 295-1541.

Kathleen A. Carlson
Manager

CONTRACTOR REQUIREMENTS DOCUMENT

1. Contractors, National Laboratories, other federal agencies, and other user organizations performing work under the purview of the National Nuclear Security Administration Nevada Site Office (NNSA/NSO) must:

   a. Identify their facilities and project activities that meet the criteria for inclusion on the Hazardous Weather Notification List.

   b. Submit facilities and project activities to be included on the Hazardous Weather Notification List to the cognizant NNSA/NSO Assistant Manager for approval.

   c. Establish lightning procedures specific to their facilities and project activities identified on the Hazardous Weather Notification List that include:

      (1) Establishment of a lightning proximity threshold boundary (minimum 10 miles) that allows sufficient time to halt work and place personnel and vulnerable assets or assemblies in a lightning safe configuration.

      (2) A process for live voice notification by the Operations Coordination Center of the facility manager or designee of lightning within the established lightning proximity threshold.

      (3) Requirements to verify current and forecast weather conditions with the Air Resources Laboratory/Special Operations and Research Division (ARL/SORD) prior to the start of facility or project activities unacceptably impacted by potential lightning hazards.

      (4) Provisions and controls for notifying personnel of a lightning alert.

      (5) Provisions and controls that place personnel, vulnerable assets, and/or assemblies in a lightning safe configuration.

      (6) Specific criteria for terminating a lightning alert.

2. In addition to the requirements above, The NNSA/NSO Performance-Based Management Contractor will:

   a. Maintain the Hazardous Weather Notification List (HWNL).

b. Validate and update the HWNL annually.

c. Provide site-wide Hazardous Weather Notifications through the Operations Coordination Center when notified of hazardous weather conditions by ARL/SORD.

d. Provide live-voice notification of facilities and project activities included on the HWNL when notified of hazardous weather conditions by ARL/SORD.

3. ARL/SORD will:

a. Maintain the capability to provide Nevada Test Site (NTS) weather forecasts.

b. Maintain the capability to detect lightning within 20 miles of the NTS boundary.

c. Notify the Operations Coordination Center when lightning has been detected within 20 miles of the NTS boundary.

d. Maintain the capability to provide specialized weather forecasts for facilities and project activities as requested.

Department of Energy
National Nuclear Security Administration
Nevada Site Office
P.O. Box 98518
Las Vegas, NV 89193-8518
APR 15 2004

Everet H. Beckner, Deputy Administrator for Defense Programs, NNSA/HQ (NA-10) FORS

REVIEW OF ELECTRICAL AND LIGHTNING PROTECTION AND DETECTION SYSTEMS FOR FACILITIES AT THE NEVADA TEST SITE

Reference letter dated November 20, 2003, subject as above.

Subsequent to the referenced letter, there were further discussions between your staff, Defense Nuclear Facilities Safety Board (DNFSB) staff, and the Nevada Site Office regarding some of the items in our response. As a result, we have clarified portions and are resubmitting our response (enclosed). My office has discussed this issue with Jack Deplitch, the DOE DNFSB site representative, and he had no major objections. However, Mr. Deplitch indicated there were several items he intends to follow up with during his next visit.

If you have any questions, please contact me at (702) 295-3211 or John L. Leppert, Acting Director for Stockpile Stewardship Division, at (702) 295-1144.

Kathleen A. Carlson
Manager

STD:JLL-04054
SHM 07-01

Enclosure:
As stated

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Response to Specific Issues
Attachment to the July 1, 2003, letter from the DNFSB Chairman
to the Administrator, NNSA

U1a:

<u>Lightning Detection Capabilities</u>—*U1a is not capable of detecting locally forming storm cells, such as the one that caused the October 1, 2002, occurrence. Given this deficiency in the facility's lightning detection and warning capability, it is not clear that certain special activities conducted at U1a are adequately safe from lightning threats. U1a personnel are investigating the implementation of field mills to detect locally forming storms that could produce lightning events. Until these devices are installed and can be effectively utilized, however, it appears that compensatory measures are required to ensure nuclear and explosive safety during U1a operations.*

The Nevada Test Site (NTS) has a lightning detection system that provides real-time data on the location of lightning strikes. This information is documented by the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory/Special Operations and Research Division (ARL/SORD) Duty Forecaster and made available via the ARL/SORD website. In addition, other resources such as weather satellite and radar are available in the preparation of weather forecasts. These are complied and disseminated in accordance with the ARL/SORD "Station Duty Manual, Volume II, Routine Duties" and the "Hazardous Weather Notification Procedure." Hazardous weather advisories, which include NTS lightning alerts, are broadcast via all radio nets in addition to telephonic notification to specific facilities. The U1a Complex has a site specific procedure (OP-2003.009, Lightning-Personnel Safety) in place that specifies actions to be taken when "lightning activity or conditions exist that may produce lightning." For worker safety, lightning within 10 miles of the U1a Complex is the threshold for taking action. This distance exceeds the nationally recognized 30-30 rule which recommends seeking shelter when lightning is six miles away (~ 30 seconds between the lightning flash and thunder clap) and waiting at least 30 minutes after the last clap of thunder or lightning flash before resuming activities.

In the October 1, 2002 case referenced above, there were no above-ground activities involving HE and/or SNM at the U1a Complex. The ARL/SORD records show a Lightning Alert was posted on the web site at 1158 PDT and individuals on the "NTS Hazardous Weather Notification List" were contacted via telephone between 1200 PDT and 1207 PDT. At that time the U1a Complex was not on this list. As a result of this incident the following actions have been taken:

1. U1a has been added to the "NTS Hazardous Weather Notification List";
2. A notification is now made by ARL/SORD if a lightning strike is observed within a 10 mile radius of the Complex. This notification is made whether or not there are surface activities involving HE and/or SNM.
3. The Lightning-Personnel Safety procedure (OP-2003.009) has been revised and enhanced.

There is further discussion under the site-wide lightning detection and warning section that addresses the issue of worker safety.

In the case of subcritical experiments (SCEs), the "Safety Evaluation Report for The Los Alamos National Laboratory and Lawrence Livermore National Laboratory Subcritical Experiment Bounding Hazard Analysis And Technical Safety Requirements" established a condition of approval (COA) requiring that a "TSR level lightning protection SS DF(s) must be developed for above-ground delivery of the SCE to the U1a Complex." Both Laboratories have established a requirement that there is no lightning within 30 miles prior to beginning delivery in response to this COA.

Legacy Cable Combustible Loading—The Board's staff observed large bundles of legacy coaxial and diagnostic cables that represent an excessive amount of combustible loading (insulation and jacket material of the cables) in the tunnel. During a fire, these cables would burn readily, allowing fire to propagate through the tunnel complex. In addition, the combustion of these materials would generate large volumes of toxic gases that could pose serious life-safety hazards to down-hole facility workers.

The combustible loading study for the U1a complex legacy cables is being prepared by BN's teaming partner (Keystone/Delphi) and is still being revised at this point to address issues raised relative to the documentation of some of the supporting information, and other comments relating to facility operations. However, the study addresses the probable risk associated with a fire in the U1a Complex leading to a fire in the legacy cables. The determination thus far is that this event is in the beyond extremely unlikely or incredibly unlikely range (on the order of 1.8E-7). Thus, the report concludes that the existing equipment design and administrative controls are adequate, and no facility modifications are warranted to address this issue. There is no firm date at this time for submittal of the study.

As far as the issue of having power cables mixed in with the diagnostic cables is concerned, the belief is that it is very unlikely that this has occurred, but not inconceivable. The only way to demonstrate that this has not occurred is to trace the individual cable bundles out to assure that there is no intermixing and, if necessary, open the diagnostic cable bundles up at discrete locations. BN Engineering is continuing to actively investigate issues relating to legacy diagnostic and power cables in the U1a Complex.

Device Assembly Facility (DAF):

Lightning Standoff Distance—The staff observed that the lightning standoff, including detailed information on the proper use of qualified, process-related isolation devices, is not adequately captured in the existing Safety Analysis Report (SAR). The establishment of sufficient clear-air standoff distance is an essential component of the lightning protection philosophy currently employed at this facility. Although a variety of documents and reports (including the Nuclear Explosive Safety Master Study and Single Integrated Input Document) provide detailed information in this area, required standoff *distances are not expressly delineated in the existing SAR. In addition, electrical isolation devices are not credited and functionally classified relative to this important safety function.*

It is unclear how standoff requirements and other important components of the lightning protection philosophy will be codified in the upcoming DAF Documented Safety Analysis (DSA) being developed to comply with the mandates of Part 830 to Title 10 of the Code of Federal Regulations, Nuclear Safety Management. To ensure nuclear and explosive safety at the DAF, the results of existing reports and analyses should be used to clearly capture and appropriately credit all elements of the lightning protection system in the new DSA.

The DAF SAR documents the standoff from the floor (2 ft.) and wall (3 ft.), while the Nuclear Explosive Safety (NES) Single Integrated Input Document (SIID) provides standoff only for the wall (3 ft.). The DAF DSA, section 3.4.2.7, Lightning Induced Accidents, provides a comprehensive discussion of lightning-energy-related threats to DAF operations both outside and inside the facility. Potential insults include: direct lightning strike (outside), induced currents through electrical connections, mechanical connection, and electrical arc. Hazards analysis has been performed for various scenarios and the results documented. Supporting studies for this analysis include the NES SIID, Pantex Site SAR, and other studies. The lightning standoff distance has been identified explicitly in the hazard analysis for the new DSA as an important administrative control requiring explicit coverage in the Technical Safety Requirements (TSRs) because of its role in preventing electrical insults during lightning events to high explosives with the potential for high-explosion violent reaction (HEVR). Section 5.6.10 of the TSRs has "maintain at least a 3-ft distance between significant amounts (>2 lb) of HE and the Affected Building walls" as a key element of the Explosive Safety Program.

<u>Unprotected Uninterruptible Power Supply (UPS)</u>—Three large UPS units are relied upon to provide emergency power to important systems throughout the facility (e.g., emergency lighting, radiation air monitors, and blast door interlocks). These UPS units are located in the electrical room and are constructed with partially open top panels that provide heat dissipation. The orientation of these units is such that they sit directly beneath sprinkler heads of the fire suppression system. Given the partially open upper panels, water spray from the sprinkler system during a fire or a spurious activation would penetrate the UPS equipment and could initiate water-induced short-circuiting, a common-cause failure that would leave emergency loads without uninterruptible emergency power.

An engineering design is in process to determine the best method for prevention of fire suppression water entering into the vents on the top of the UPS units. Change Request #DAF-CT-0861 has been initiated to resolve this issue. The Change Request will be implemented through the normal configuration management process and executed as funding becomes available. It is anticipated this work will be completed by the end of FY 04.

<u>Calibration of Protective Devices</u>—To ensure reliable operation, Institute of Electrical and Electronic Engineers (IEEE) Standard 242-2001, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems, recommends that electrical protective devices be maintained and calibrated in accordance with manufacturer's instructions. During a walkdown of the electrical room, the Board's staff observed that the calibration date had expired by several years for many of the protective devices. DAF personnel stated they would verify that required calibrations had been performed or perform the calibration tests on the expired relays to ensure that they will operate within allowable limits.

The requirement for calibration of the Siemens Westinghouse SPB-100 breakers and ground fault relays has been researched. Based on conversations with the manufacturer's Senior Account Manager, the tolerance of the relays will vary over time and require maintenance and calibration at a regular basis with a periodicity dependent upon service and environment conditions (generally 3 to 4 years). This activity has been incorporated into the DAF preventive maintenance program to ensure it is performed during the recommended intervals.

<u>Pressure Alarm</u>—Compressed air is required for closing and opening of critical cell and bay doors. Compressed air accumulators have pressure gauges, but no alarms annunciate in the control/operator's room upon loss of air or low pressure. Compressors for the air accumulators are located outside the main DAF building. If pressure were lost during operations, however, manually opening the doors during an emergency would be difficult. Procedural administrative controls exist at the DAF to check for air pressure prior to any operation. An alarm to annunciate low air pressure would provide a more reliable system for determining the operability of these critical cell and bay doors.

Metasys, the DAF automated energy management system, provides a low air pressure alarm function. Additional defense-in-depth features include: a Metasys alarm if one of the three compressors fail and the existence of an air tank at each building that allows five cycles of the door. These features provide adequate assurance for egress from DAF facilities during emergency conditions.

<u>Oil-Insulated Transformer</u>—Two oil-insulated transformers located inside the DAF structure are parts of the facility power distribution system. The transformer oil provides cooling for the transformer. Because the oil is flammable, it poses a fire hazard should the transformer leak or fail catastrophically. American National Standards Institute (ANSI) C2, National Electrical Safety Code, and National Fire Protection Association (NFPA) 70, National Electric Code, require that indoor oil-insulated transformers be located in a separate transformer vault. The code requirements for the transformer vault include fire walls and doors, ventilation, and oil containment. The DAF transformer is collocated with other electrical equipment, and the fire wall is breached by several cables in metal trays that are routed through the room. In addition, the cables could be damaged during a fire, and the loss of any function they provide needs to be evaluated.

A recent safety walk down of the transformer room determined that DAF transformers are currently located in a transformer vault that provides a minimum fire resistance of three hours. Fire dampers are provided in ventilation openings. Penetrations have an approved fire rated sealant. At this time a few require resealing which will be accomplished as part of the scheduled maintenance. Oil containment (curb/dike) is provided with a line that drains to an underground tank in the DAF forecourt. The transformer vault meets the National Electrical Code handbook (1999) requirements. The oil in the transformers was sent to a laboratory to verify the material and the report is being evaluated against applicable codes and standards. The walk down noted combustible items being stored in the transformer room. These items will be evaluated for relocation. Both evaluations should be completed by the end of March 2004.

There are a few cables that enter the transformer room per design. Two of the cables are for the Plant Announcement and lighting systems that are provided for the transformer room. A fire alarm cable is also provided for a speaker in the transformer room and adjacent corridor. Another cable that traverses the room supports the Radiation Alarm Monitoring System. The remaining cables are associated with the power distribution system and transformers in the room. The potential impact of a fire in the transformer room is expected to be mitigated by the installed fire suppression system and fire barriers and was not identified as a vulnerability in the DAF Fire Hazards Analysis or Documented Safety Analysis. The Safety Basis Implementation Plan for the DAF will ensure applicable contractual requirements are implemented (e.g., NFPA 70 – National Electric Code) in accordance with NNSA expectations.

G-Tunnel:.

Ventilation System – Electric motors, motor controllers, and power cables (which are located outdoors) at G-Tunnel are old and degraded. The Board's staff observed severely damaged power cables, some with badly cracked jacket material, installed and routed through open vertical conduits. Water may have entered through these open conduits and deteriorated the electrical characteristics of the cable. The ventilation fan motor controllers were observed to be quite antiquated and exhibited a good deal of age-related wear. As a result, it was not clear that these components could be relied upon to perform their intended life-safety function. Given concerns regarding worker life-safety, it would be prudent to evaluate the complete ventilation system, including electric motors, controllers, cables, and the installed ventilation ducts inside and outside the tunnel.

The cables that were identified at the time of the walk-through were inactive cables and were abandoned sometime in the 1980's. Rather than cut the conduit and cable off flush with the concrete pad, BN personnel installed a small water-tight enclosure over the protruding conduit. No further action is required.

Failure of the system would not cause an imminent life-safety issue. In the event of a failure, personnel would make an orderly evacuation of the underground complex. All systems will be shut down with the exception of utility power, compressed air, and water.

If required, operations could actually continue underground during a ventilation system failure providing there is continuous monitoring by Industrial Hygiene personnel and contaminant-producing equipment is eliminated. In the event of a ventilation system failure coincidental with an underground emergency, personnel would don their self-rescuers and report to the refuge chamber, exactly as they would with the ventilation system operating. A dedicated compressed air line supplies fresh air to the refuge chamber.

The ventilation system is antiquated and its continued, long-term operability is questionable. A thorough evaluation of the ventilation system is prudent; however; given the age of the system components, better use of limited funding would be to prepare a proposal to replace the entire fan/starter system and evaluate the ventilation ductwork for segmented replacement. BN is developing an estimate for the required work. This should be completed in late February or early March 2004.

Site-wide Lightning Detection and Protection: *The Board's staff made the following general observations regarding lightning detection, warning, and protection capabilities of the nuclear facilities at NTS.*

Several facilities at NTS, including the DAF, JASPER, and U1a, perform operations in which SNM is collocated with significant quantities of HE. To protect these operations from lightning-related insults, both the DAF and U1a employ a 10-mile lightning proximity threshold. A strike inside this boundary triggers a halt-work order and the initiation of measures aimed at placing potentially vulnerable assemblies in a lightning-safe configuration and location. Unlike the Pantex Plant, however, DAF and U1a do not appear to have a defensible technical basis for ensuring that a 10-mile threshold can provide adequate forewarning to make potentially sensitive assets lightning-safe. Pantex uses a 35-mile lightning proximity threshold to declare cessation of nuclear explosive work. This threshold was derived from thorough evaluations predicting worst-case shutdown times for all approved nuclear explosive operations. It appears that this type of evaluation, or some other technically rigorous analysis, is warranted and necessary to ensure nuclear and explosive safety at the NTS facilities.

Lightning scenarios could initiate high-consequence accidents at NTS facilities where operations (normal or otherwise) involve SNM collocated with HE. Some operations involving SNM and HE could commence at various NTS facilities with little or no forewarning. However, not all of the facilities that could potentially house these operations are currently equipped with adequate lightning detection capabilities or well-documented lightning protection controls. It would be prudent to devise and ready for operation compensatory measures designed to mitigate potential lightning hazards until robust lightning detection and protection programs have been adequately documented and implemented at affected onsite facilities.

The Lightning Focus Group (LFG) is planning several actions. The first is to develop a site-wide policy on lightning safety which will require selected facilities prepare procedures to address actions to be taken when lightning is present based on the risk.

The second is to conduct a study on the effectiveness of field mills at the NTS. While the exact study protocol has not been developed, it is anticipated this study will take several years to complete to ensure a representative sample of thunderstorms is used to validate the effectiveness of field mills at the NTS.

Delivery of experiment packages requires no lightning within 30 miles of the DAF or U1a. For SCEs underground at U1a, procedures are in place to prevent an electrical insult from impacting the experimental package. OP-2003.009, Lightning-Personnel Safety, also specifies actions to be taken at the U1a Complex when lightning is present. The DAF has been designed as a Faraday cage and there are field mills around the facility. The field mills and ARL/SORD lightning information are monitored whenever HE operations are in progress in accordance with DAF Procedure DAF-PRC-TO-02, Lightning Threat Warning System. In addition there is a stand-off distance between the building walls and HE. There is a field mill located in Area 27 near the JASPER facility. LLNL has a procedure, NTO-NTS-308, Lightning Detection and Protection at the Nevada Test Site, covering its activities at the NTS.

SORD Technical Memorandum: SORD-2006-02

Investigation of Range-Applicable Lightning Detection Systems

Darryl Randerson
Walter W. Schalk

Air Resources Laboratory
Silver Spring, Maryland
March 2006

noaa NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

Notice

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ABSTRACT

An investigation of current operating lightning activity/potential monitoring systems was conducted. Ten Federal facilities were identified and contacted. Three facilities were visited. Four primary systems were identified across all facilities: Field Mills, Magnetic Direction Finders (MDF), the National Lightning Detection Network (NLDN), and Lightning Detection And Ranging (LDAR) systems. One facility employed all four systems, while two facilities use three of the systems. The primary capability used by these three facilities was the MDF system. These facilities did have field mills; however, the primary purpose was to determine the static electrical field and not to determine lightning activity or potential.

INVESTIGATION OF RANGE-APPLICABLE LIGHTNING DETECTION SYSTEMS

Darryl Randerson and Walter W. Schalk

ARL/SORD
Las Vegas, Nevada

1. Objective

To investigate current operating systems that detect lightning and are used to guard the safety of personnel, to protect property, and to help safeguard sensitive equipment.

2. Methodology

- Identify significant operational facilities that may have a requirement to monitor lightning activity or the potential for lightning strikes.
- Review technical literature and identify lightning detection and tracking systems.
- Contact the identified facilities to obtain information about their activity/potential monitoring systems. Make site visits where appropriate.
- Analyze data collected.
- Prepare draft report and present to Lightning Focus Group.
- Address comments.
- Prepare final report.

3. Findings

Table 1 lists the facilities that were contacted regarding lightning detection and monitoring systems. The facilities contacted ranged across the Federal community. A majority of the locations are DOE/NNSA sites; however, NASA, DOD, and NOAA are represented. Table 2 summarizes the lightning detection capabilities at these facilities. The capabilities fell into four categories; Field Mills, dedicated Magnetic Direction Finders (MDF), the National Lightning Detection Network (NLDN), and Lightning Detection And Ranging (LDAR) systems.

Table 3 lists technical characteristics of the four primary lightning detection systems used by the major Federal facilities contacted. The systems used at the NTS are shaded in blue.

Table 4 lists the number of sensors for each system installed at the facilities contacted.

Table 1: Facility and Contact Type

Facility/Organization	Federal Affiliation	E – mail	Telephone	Site Visit
Cape Canaveral / KSC	NASA	X	X	
PANTEX	DOE / NNSA	X	X	X
LANL / DX	DOE / NNSA	X	X	X
NTS	DOE / NNSA	NA	NA	NA
SRL	DOE / NNSA		X	
INEEL	DOE / NNSA		X	
Richland	DOE		X	
YMPO	BN / SAIC	X	X	
White Sands	DOD		X	
Severe Storms Lab	NOAA		X	
New Mexico Tech	NA			X

Table 2: Lightning Detection Capabilities at Major Facilities

Facility/Organization	Field Mills(1)	Dedicated MDF	NLDN	LDAR / LMA
Cape Canaveral / KSC	X	X	X	X
PANTEX	X	X	X	
LANL / DX	X		X	
NTS	X	X	X	
SRL	X		X	
INEEL				
Richland			X	
YMPO		X(2)	X	
White Sands			X	X(3)
Severe Storms Lab	NA	X	X	X
New Mexico Tech			X	X

RED denotes primary system used.
(1) Measures electric field strength
(2) Uses access to NTS MDF system
(3) LMA being installed

Of the eleven facilities listed in the tables, three standout as having a substantial total capability. These facilities are Cape Canaveral / KSC, PANTEX Plant, and the Nevada Test Site.

The most extensive lightning detection system is at Cape Canaveral / KSC in Florida. Their total capability uses all four of the systems outlined in this investigation. Each system has a primary purpose in support of KSC missions. The primary system for lightning activity information is the Magnetic Direction Finders (MDF). The KSC uses field mills in support of rocket launch activities to detect the static electricity field near the launch facility. A high static electrical field measurement can postpone a rocket launch. As explained by KSC personnel: The exhaust from a rocket is plasma-like which acts as a conductor and compresses the existing static field. If the existing static field is large enough, the rocket will create a lightning strike upon itself that can have very catastrophic effects.

Table 3: Technical Characteristics of the Primary Lightning Detection Systems (NTS Systems are in blue)

	Field Mills(1)	Dedicated MDF	NLDN	LDAR / LMA
Sensor Spacing	8 – 16 km	40 – 75 km	200 – 400 km	6 – 10 km
Effective Range	10 – 20 km	200 – 300 km	National	100 km
Lightning Detected	All (Flash Strength)	Cloud-to-Ground	Cloud-to-Ground	All
Flash Detection Efficiency	≥90%	95%	80% – 90%	≈100%
Location Accuracy	2 – 20 km	0.5 km	0.5 – 1.0 km	0.1 km
Peak Location Rate	80 – 85 min^{-1}	80 – 90 min^{-1}	800 min^{-1}	10,000 min^{-1}
Source	Commercial	Commercial	Commercial	Research
Operational	Yes	Yes	Yes	No
Customers	Few	Many	National	Limited
Approximate Cost Installed	\$5,000 - \$10,000 (each)	\$350,000 (3 – 5 DFs)	NA	\$400,000 - \$600,000

NTS Systems are shaded blue.
(1) Measures electric field strength

At the Nevada Test Site (NTS), the MDF capability is also the primary site safety system for detecting and tracking lightning activity. NTS procedures for personnel and operational safety are linked to information received from these lightning sensors and interpreted by National

Oceanic and Atmospheric Administration (NOAA) ARL/SORD staff. The primary function of field mills on the NTS is to detect the static electrical field in the environment surrounding explosive and hazardous materials. In addition, SORD meteorologists have the following assets to assist in the prediction of thunderstorm activity and detect and track lightning:

- NOAA NEXRAD RADAR,
- NOAA weather satellite imagery (GOES West),
- SORD NTS weather network,
- SORD upper-air sounding system (GPS and NOAA microARTS),
- DRA surface weather observations, and
- Local/national atmospheric stability/thunderstorm prediction parameters.

The PANTEX Plant in Amarillo, TX, employs the same capabilities as the NTS. The primary capability for site safety is the MDF system. Plant procedures for personnel and operational safety are linked to information received from these lightning sensors. PANTEX also uses field mills. The primary function of the field mills is to detect the static electrical field in the environment surrounding the movement and disassembly/assembly of hazardous materials.

Table 4: Lightning Detection and Tracking Sensors for Major Facilities

Facility/Organization	Field Mills(1)	Dedicated MDF	NLDN	LDAR / LMA
Cape Canaveral / KSC	31	5	105	7
PANTEX	3	4	105	
LANL / DX	6		105	
NTS	6	6	105	
SRL	1		105	
INEEL				
Richland			105	
YMPO		6	105	
White Sands			105	1
Severe Storms Lab	NA	1	105	1
Lightning Research Center, AZ				

RED denotes primary system used.
(1) Measures electric field strength

Four different lightning activity/potential monitoring systems have been identified. After gathering information from the various sites, benefits and shortcomings of each system can be identified. Table 5 displays this analysis.

Table 5: Benefits and Shortcomings of the Four Primary Lightning Detection/Potential Systems

System	Benefits	Shortcomings
MDF and LDAR	- Indicates when the atmosphere is becoming electrically active - Displays electrical activity on maps as occurring - Indicates the movement of electrical activity - Indicates the amount of electrical activity - Indicates the trend of electrical activity - Indicates when the electrical activity is diminishing - Detection capability covers a large area, allowing time to assess local safety issues and provide warnings	- High Cost - Need at least 2 DFs; 3 preferred - Limited range (< 300 km) - Requires professional interpretation
Field Mills	- Low Cost - Easy to Use - Detect all electrical discharges - Detect electrical potential	- Limited Range (not much better than eyes and ears) - Limited display capabilities - Threshold must be identified - False-positive alerts
NLDN	- Low cost - Low maintenance - Easy to Use - Indicates when the atmosphere is becoming electrically active - Displays electrical activity on maps as occurring - Indicates the movement of electrical activity - Indicates the amount of electrical activity - Indicates the trend of electrical activity - Indicates when the electrical activity is diminishing - Detection capability covers a large area, allowing time to assess local safety issues and provide warnings	- Not site specific - Limited accuracy

4. Summary

After investigating the capabilities and systems employed by ten federal operational facilities, four primary capabilities were identified. One facility, Cape Canaveral / KSC, used all four, while two facilities, NTS and PANTEX, used three. The site missions of the NTS and PANTEX have some general similarities, but contrast greatly with the Cape Canaveral / KSC mission. However, the over-arching purpose is for personnel and operational safety. The primary system at all three facilities was the MDF capability. While these three facilities do use field mills, the purpose of the information received from them was neither to determine lightning activity nor potential, but rather to measure the static electric field in explosive and hazardous material areas.

Field mills are used at one facility, LANL, as the primary system. Overall, four facilities use MDFs as the primary system, and three use the NLDN. The LDAR/LMA is a research grade system that is being evaluated and is not available commercially. Based on conversations with system developers, the addition of an LDAR/LMA system to the NTS might increase the lightning detection envelope by 5 to 10 minutes.

Activities completed and final comments:

- Assessed lightning detection and tracking systems at 10 major federal facilities
- Four different systems/networks were identified
- Compared the NTS system with those at other facilities
- Field mills serve as the primary lightning detection system at only one site, LANL
- Number of field mills at NTS is adequate to meet operational needs
- The MDF system is the primary system at 4 sites and the NLDN is primary at 3 facilities
- The LDAR/LMA is primarily a research grade system that is being evaluated and is not in commercial production
- Addition of LDAR/LMA might increase lightning detection safety envelop by 5 to 10 min.
- Recommend reanalysis when LDAR/LMA system becomes operational and available.
- The NTS MDF system was designed to provide very high resolution on the NTS (within 0.25 km), provide high sensitivity (detect 95 to 98% of cloud-to-ground lightning), and streamline data flow to customers.

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Analysis of Thunderstorm Forecasts and Cloud-to-Ground Lightning in the Vicinity of the Nevada Test Site

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Silver Spring, Maryland
February 2006

noaa NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

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ABSTRACT

Summertime (June through September) cloud-to-ground (CG) lightning flash activity in the vicinity of the NTS was analyzed for 2003 and 2004. These data were melded with the SORD daily weather forecasts to permit evaluation of the reliability of forecasts of thunderstorm activity on the NTS. A total of 83% of the thunderstorm/CG predictions were correct. Based on the analysis of local upper-air soundings taken on thunderstorm days, a representative speed of movement of thunderstorm activity across the NTS is 20 mph. Additional analysis of the time of occurrence of thunderstorm and CG lightning data showed that if thunderstorms are forecast in the 0800 LT NTS weather forecast package, a two-hour window of safety exists prior to the occurrence of thunderstorms and CG lightning on the NTS.

ANALYSIS OF THUNDERSTORM FORECASTS AND CLOUD-TO-GROUND LIGHTNING IN THE VICINITY OF THE NEVADA TEST SITE

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I. Introduction

Thunderstorms and the lightning activity accompanying them can not only damage property and sensitive equipment, but are also a safety hazard for personnel working on and around the Nevada Test Site (NTS). In addition, these storms can be accompanied by strong surface winds and heavy precipitation that can cause flash flooding. Although thunderstorms can occur all year, Quiring (1983), Randerson (1997), and Skrbac (1999) have shown that 75-80% of the thunderstorms over southern Nevada occur during the summer months; June through September. Moreover, Randerson and Sanders (2002) have characterized cloud-to-ground (CG) lightning activity on the NTS. Their analysis shows a large inter-annual variation in CG lightning on the NTS, a peak in flash activity between 1300 and 1500 PDT, the effect of terrain, and a CG flash rate of 50 to 75 fl/hr in the most active thunderstorms.

Forecasting thunderstorm activity on the NTS is provided by National Oceanic and Atmospheric Administration (NOAA), Air Resources Laboratory (ARL) research meteorologists/forecasters working at the Special Operations and Research Division (SORD). Weather forecasts for the NTS are issued twice daily, Monday through Friday, at 0800 and 1500 LT. Hazardous weather advisories and lightning alerts are issued as required to a wide variety of programs conducted on the NTS. Lightning data are acquired from the NTS Lightning Detection System operated and maintained by ARL/SORD. This system and the Lightning Alert process have been described by Randerson and Sanders (1999) and updated by Randerson (2004).

II. Data

Summertime (June through September) cloud-to-ground (CG) lightning flash activity in the vicinity of the NTS was analyzed for 2003 and 2004. Data were tabulated for a total of 244 days. CG flash activity was stratified into two categories; namely, CG flashes that were detected within the 20-mi Lightning Alert Area and those that occurred on the NTS. A total of 33,024 CG flashes were detected within the Alert Area. Of these flashes, 7036 (or 21%) were detected on the NTS. Days on which the CG flashes occurred within the 20-mi Alert Area were identified as CG lightning or thunderstorm days. These data were melded with the SORD daily weather forecasts to permit evaluation of the reliability of forecasts of thunderstorm activity on the NTS. The NTS weather forecast package used was the one issued by the SORD Duty Forecast at 0800 PDT, Monday through Friday. All these forecasts were scanned to identify the days on which thunderstorms were forecast for the NTS. In addition, the dates on which Lightning Alerts were issued were also tabulated for the summers of 2003 and 2004. These days were identified as CG lightning, or, thunderstorm days.

Another data file was created to capture the estimated mean transport speed of thunderstorms near the NTS. This file was created by using the dates on which NTS thunderstorms occurred and the archive of atmospheric upper-air soundings taken twice daily at the Desert Rock Meteorological Observatory (DRA); at 0500 PDT and 1700 PDT. The results of all the analyses of these data are described next.

III. Results

NTS thunderstorms prediction and CG lightning:

Of the total number of 0800 PDT forecasts issued, there were 58 forecasts for thunderstorms on the NTS and 61 CG lightning days. Lightning Alerts were issued for all thunderstorm days, except for three days. On one day, the lightning occurred off the NTS and after hours so that no one was on duty at DRA. In the other two cases, the Duty Forecaster decided not to issue an Alert because the thunderstorms were not on the NTS, were dissipating, and were moving away from the NTS. In both cases a single CG flash was detected just inside the Alert Area.

The contingency table shown in Table 1 summarizes these data. For the thunderstorm or CG lightning days, 78% were predicted correctly and 21 % were not. If one deletes the three anomalies above; the correct score rises to 83%. Of the other "no" forecasts, NTS Lightning Alerts were issued immediately, as required. Thunderstorms did not occur on 10 days (4%) for which they were forecast. Overall, 91% of the forecasts were correct.

Table 1. NTS thunderstorm predictions versus observations of CG lightning; number of events.

		CG Lightning Observed	
		Yes	No
NTS Thunderstorm Predicted	Yes	48	10
	No	13	173

CG Lightning Days and Issued Lightning Alerts:

Lightning Alerts were issued on all days during which thunderstorms occurred within the 20-mi Lightning Alert Area. On a few days more than one lightning alert was issued; either to extend the alert to a later time or to issue a new alert late in the day after one issued early in the morning had expired. Days with one or more Alerts were classified a lightning alert day. Table 2 presents the data on this comparison. The three anomalies are explained in the previous section. Skill in issuing Lightning Alerts is obvious.

Table 2. CG flashes detected within the Alert Area versus Lightning Alert Days; number of events.

		Lightning Alert Issued	
		Yes	No
CG Lightning Observed in Alert Area	Yes	58	3
	No	0	180

Thunderstorm Translation Speed:

A solid technical basis for establishing a representative speed of movement for thunderstorms lies in the DRA atmospheric sounding data collected twice daily, at 0500 and 1700 PDT, to altitudes near 30 km. To create the required data base, first, all summer days with CG lightning within the 20-mi Alert Area were tabulated and identified as NTS lightning or thunderstorm days. A day with one or more Lightning Alerts and, or, with early morning thunderstorms followed by afternoon thunderstorms and late evening storms is a lightning or thunderstorm day. As shown in the above tables, there were a total of 61 lightning days.

Second, archived upper-air sounding data for DRA were accessed for each lightning day. Mean thunderstorm speed of movement was determined by estimating the average wind speed between the 700-mb and 300-mb levels, or, approximately, between the 10,000-ft and 30,000-ft levels above mean sea level. The speed data were then separated into 5 mph categories ranging from 0-5 mph to 46-50 mph. These data are summarized in Figure 1. The data show that on 56% of the lightning days, thunderstorm translational speeds were ≤ 20 mph. Of the days with faster speeds, 15% occurred in late spring or late summer.

Operationally, SORD Duty Weather Forecasters can accurately determine thunderstorm translational speeds from the twice-daily upper-air soundings taken at DRA. If speeds greater than 20 mph are measured, the forecaster can easily factor this information into the Lightning Alert process, providing ample time for response by safety personnel. Moreover, the forecaster has access to high resolution NOAA satellite imagery of southern Nevada, to NOAA weather radar data, and to 15-min meso-scale meteorological data from the NTS. All these data sources are monitored by the Duty Forecaster and used to track weather conditions and to make the best possible thunderstorm/lightning forecasts for the NTS.

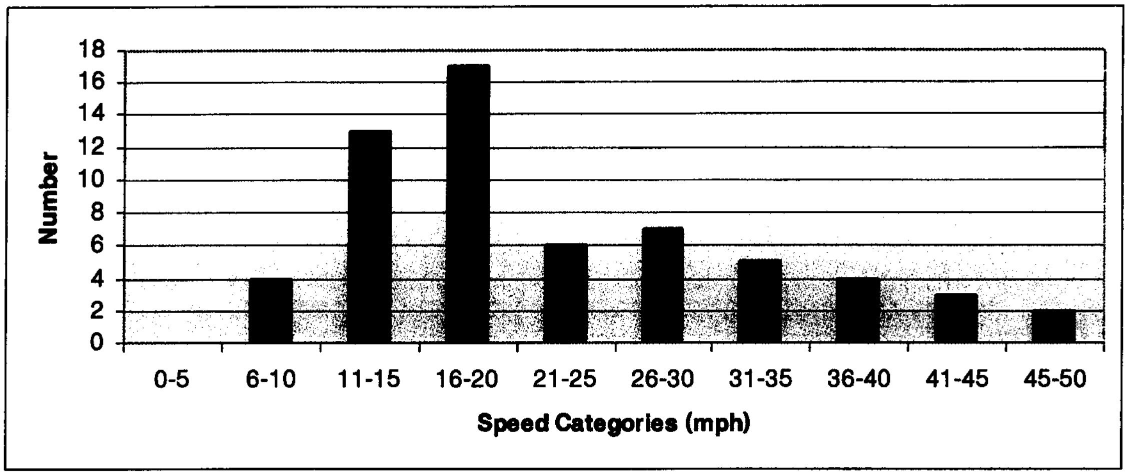

Figure 1. Distribution of Thunderstorm Mean Transport Speeds for 61 NTS Thunderstorm Days, June through September, 2003 and 2004.

Timeliness of NTS Thunderstorm Forecasts

To evaluate the beginning of CG lightning within the 20-mi Lightning Alert Area relative to the forecast of thunderstorm (and lightning) activity, the CG lightning data base was accessed to identify the time of occurrence (PDT) of the first CG flash. These data were matched with the days during which thunderstorms were forecast for the NTS in the 0800 PDT forecast package. Figure 2 portrays the results of this analysis. The figure shows that 85% of the thunderstorms and CG lightning detected within the 20-mile Alert Area occurred after 1000 PDT, or at least, 2 hrs after the 0800 PDT forecast for NTS thunderstorms was issued. Consequently, NTS personnel had at least a two-hour advisory of the potential for thunderstorms and CG lightning on the NTS. For the 15% of the events occurring prior to 0800 PDT, Lightning Alerts were issued by SORD Physical Science Technicians working at DRA in all cases except the one that occurred between 0000 and 0100 PDT when DRA was unmanned.

IV. Summary

- A solid technical basis for establishing a representative speed of movement for thunderstorms is given based on meteorological data collected on the NTS.
- When thunderstorm activity is included in the 0800 PDT NTS forecast package, personnel working on the NTS normally have, at least, a two-hour window in which to prepare to implement safety actions should a Lightning Alert be issued by SORD personnel.

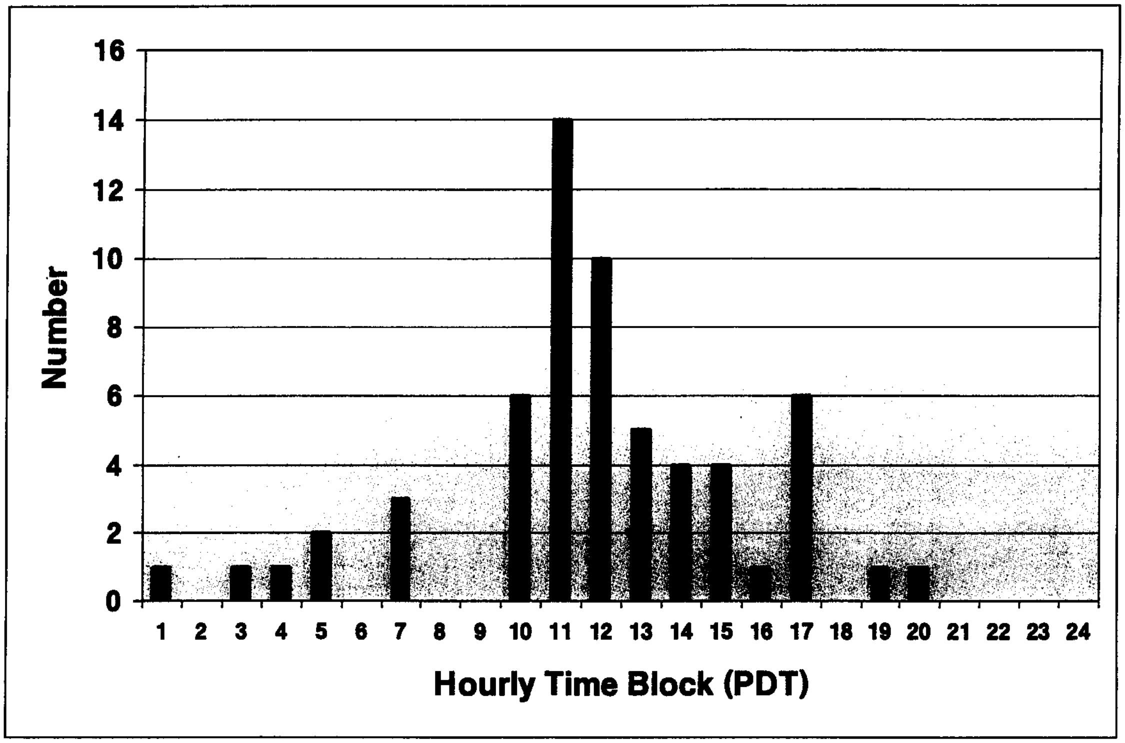

Figure 2. Distribution of the time of detection of the first CG flash within the 20-mile Lightning Alert Area on days when thunderstorms were forecast for the NTS in the 0800 PDT forecast package.

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