6.3 LIGHTNING PROTECTION AT THE KENNEDY SPACE CENTER AND CAPE CANAVERAL AIR FORCE STATION

Pedro J. Medelius *
Dynacs, Inc., Kennedy Space Center, Florida

William P. Roeder
45th Weather Squadron, USAF, Patrick AFB, Florida

J. Willingham
NASA, Kennedy Space Center, Florida

1. INTRODUCTION

Frequent lightning activity in Florida has resulted in the need for effective lightning protection systems at the Kennedy Space Center (KSC) and at Cape Canaveral Air Force Station (CCAFS). Critical flight hardware, such as the Space Shuttle vehicle launched from KSC and the expendable launch vehicles (ELV's) launched from CCAFS, must be protected against direct lightning strikes, including their indirect effects, and the effects of nearby strikes. Electronic equipment is susceptible to damage when exposed to voltage beyond safe limits. Lightning strikes, which usually carry currents on the order of several thousand amperes, generate large magnetic fields with fast rise and decay times. These fast varying electric and magnetic fields result in induced voltages and currents on any conductor, which, if attached to an electronic device, can cause immediate failure of the device, or cause lesser damage which can significantly reduce its lifetime. An even more dangerous situation could result from a direct lightning attachment to an explosive or flammable device in a space vehicle or a storage facility.

Statistical and probability studies of lightning strike and damage data performed at KSC/CCAFS over the years have resulted in a comprehensive set of lightning protection systems and methods. For instance, different techniques have been applied to KSC's launch pad structures to estimate the lightning protection effectiveness for the gaseous oxygen vent arm. In-depth studies of indirect effects caused by nearby lightning strikes have also affected the lightning protection criteria. Studies have also been made to determine the magnetic field environment in and around the Payload Changeout Room (PCR) of the Space Shuttle when the complex is struck by lightning.

* Corresponding author address: Pedro J. Medelius, Dynacs, Inc., M/S DNX-10, Kennedy Space Center, FL 32899; e-mail: pedro.medelius-1@ksc.nasa.gov

2. LIGHTNING MEASUREMENTS AT THE SPACE SHUTTLE LAUNCH PADS

The Kennedy Space Center is located in a region with significant lightning activity. The possibility of a lightning strike at the surface or aloft is a hazard that must be avoided during launches and during ground activities. Lightning activity at the Space Shuttle launch pads is monitored in several ways. Local instrumentation and remote measurements provide an indication of lightning strike locations and induced voltages or currents into conductors.

A network of magnetic direction finder antennas is used to locate ground strikes in the KSC area. Individual antennas provide an azimuth angle to a particular lightning strike, and the location is determined by the intersection of the azimuth lines from different antennas. The accuracy of the system is in the order of a few hundred meters within the KSC area.

The Lightning Detection and Ranging (LDAR) system has shown to be highly useful to the spacecraft launch community in reducing the hazards associated with lightning activity, through a combination of effective detection and display technologies. The system was designed to map the location of intracloud and cloud-to-ground lightning based on the time of arrival of the electromagnetic radiation. The location system consists of 7 VHF radio receivers centered at 66 MHz., and displays intracloud lightning activity in real-time.

A lightning strike location method currently in use at the pads involves the use of a set of video cameras pointing at different locations within the Pad. If a lightning strike occurs within the field of view of three or more cameras, the location of the strike can be determined. However, if the cameras are not pointing in the correct direction, or their field of view is obscured by either the Pad structure or by a heavy downpour, the determination of the striking point becomes difficult, and in some cases impossible. There is often an uncertainty as far as the location of the exact point of contact to the ground. A new, very accurate, lightning location system is being implemented at the Launch Pads. The Sonic Lightning Location (SOLLO) system is based on the use of both electric field and thunder measurements, and can achieve 5-meter accuracy for lightning strikes within the pad perimeter. The SOLLO System will enable the users to accurately determine the attachment point of a lightning strike. This will provide important information that can be used to determine if any equipment and/or instrumentation needs to be retested or evaluated for hidden damage.

Measurements of induced voltages are conducted using transient recorders connected to selected power and communication cables. The Lightning Induced Voltage Instrumentation System (LIVIS) consist of a fast sampling recorder with deep memory storage, which allows for the recording of multiple strikes within a lightning flash with high temporal resolution. Voltages and currents from direct lightning strikes on the launch pads' catenary wire lightning protection are also monitored. The Catenary Wire Lightning Instrumentation System (CWLIS) is used to measure the current on the catenary wire following a direct lightning strike. Occasionally, nearby lightning discharges induce enough current into the catenary wire for the CWLIS to detect and measure it.

Portable, self contained, wideband electric and magnetic field sensors can be placed at selected locations to evaluate the intensity of the electromagnetic fields during a thunderstorm. These sensors record and store waveforms to be used for detailed analysis of the shielding effectiveness of the pad structure.

3. LIGHTNING PROTECTION AT KSC AND AT CCAFS

Protection for personnel and equipment is of utmost importance at KSC and CCAFS. Warnings are issued when lightning activity is expected in the area, and when lightning activity is in progress. Warnings allow personnel to evacuate a dangerous area during a thunderstorm, and to secure the area if needed to reduce the potential for lightning damage to equipment and instrumentation.

Lightning protection at the Space Shuttle launch pads is provided primarily by a 70-foot insulating fiberglass mast 5 feet in diameter located on the Fixed Service Structure with a lightning rod at the top of the mast, as shown in Figure 1. A catenary wire running from the top of the mast to grounding points 1000 feet to the north and south of the tower is used to direct the current away from the pad structure. The lightning protection mast is struck an average of three times per year. Nevertheless, there have been instances when a lightning flash has traveled past the catenary wire protection system and has directly struck the launch pad structure. The effectiveness of the catenary wire protection was studied and modeled by Stahmann (1). The study provided the probability of lightning striking different points of the pad structure past the catenary wire protection, and resulted in a probability of one strike to the Space Shuttle vehicle once every 100 years.

Figure 1. Space Shuttle launch pad lightning protection mast.

A comprehensive study was performed to understand and identify the risks to payloads as they are brought into position at the PCR, loaded in to the cargo bay of the Space Shuttle Orbiter, and checked out prior to flight. The results of analysis using numerical techniques were compared against measurements performed using a lightning simulator used to inject a large current into the catenary wire. It was concluded that as long as the Orbiter was grounded to the PCR, it was unlikely that a lightning flash to the catenary wire would cause enough voltage to present a hazard to personnel in the PCR. However, there could be enough voltage to cause damage to electrical and electronic equipment not properly grounded and shielded either on the PCR or on a payload (2).

Protection against direct lightning strikes has also been implemented at selected facilities at KSC and at CCAFS, as shown in Figure 2. Overhead grounded protective grids are used at various installations to protect equipment and personnel working underneath. Expendable Launch Vehicle (ELV) pads, such as the Titan IV, are protected in a similar way.

Figure 2 Lightning protection masts and overhead protective grid for the Titan IV launch pad at CCAFS.

4. PLANNED STUDIES

The understanding of the effects of transient voltages and currents induced into conductors is important to allow for the design of protection systems for flight hardware and for personnel working in the area. Different structures respond in different ways to excitation from a lightning strike. Unique problems can result from slow-decaying oscillations in a metallic structure, which can resonate at certain frequencies. For instance, a lightning strike to the catenary wire at the Space Shuttle launch pads, results in multiple reflections back an forth the wire as a result of mismatched impedance between the catenary wire and the ground. This results in a strong component at a few hundred kHz with several large harmonics which could potentially result in large induced voltages on certain conductors.

The needs for NASA's EVL Pegasus program are being evaluated for its potential exposure to lightning damage. Sensors for monitoring of transient voltages and magnetic fields will be installed at various locations. The goal is to provide a more effective protection of the spacecraft from direct and indirect lightning effects and improve the prediction capability of induced voltages, currents and electromagnetic fields on the spacecraft hardware.

Analysis of the potential for damage inside ELV processing buildings is also in progress. Metallic high bay buildings with open ends can behave as resonant cavities, thus resulting in large electromagnetic fields inside. Coupling of these fields into power and communication conductors can result in voltages large enough to damage electronic equipment. The outcome of the study is expected to provide a better understanding of the magnitude of the fields that can be expected inside such structures. These results can be used to determine ways to improve the shielding effectiveness and to minimize potential damage to sensitive components.

5. CONCLUSIONS

The design of lightning protection methods, lightning sensing equipment, and lightning location systems is an ongoing process at KSC and CCAFS. The unique nature of the space-related activities, coupled with the relatively high incidence of lightning activity in the central Florida area, has resulted in increased attention to lightning and its direct and indirect effects. Analysis of data collected over the years, as well as that obtained from new measurements is expected to result in better protection systems for both personnel and equipment.

6. REFERENCES

(1) Stahmann, J.R., Launch Pad Lightning Protection Effectiveness, *1991 International Aerospace and Ground Conference on Lightning and Static Electricity*, 1991.

(2) Fisher, F.A., Study of Lightning Effects at the Payload Changeout Room (PCR), August 1992