Proceedings and Minutes of the National Interagency Coordination Group Meeting

Low Altitude Direct Strike Lightning Characterization Program

January 28-30, 1985

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September 1985  
Proceedings

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The meeting was held at the Kings Inn Motel, St. Louis, MO

This publication is a composite of the minutes, and presentations given at the Sixth National Interagency Coordination Group on Lightning and Static Electricity meeting, held in St. Louis, MO January 28 and 29, 1985. Mr. Dave Albright of the Aviation Systems Command, U. S. Army, St. Louis, MO, was the host.

The presentations encompassed both the active and anticipated programs from each agency.

Note: Considerable latitude was exercised in the literal transcription of the proceedings to alleviate extensive delays in the publication of the document.

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*Presentation not submitted for inclusion into minutes.*
EXECUTIVE SUMMARY

The sixth meeting of the National Interagency Coordination Group (NICG) sponsored by the Aviation System's Command, was held at the Kings Inn, St. Louis, MO on January 28 and 29, 1985. In addition, the NICG sponsored the Low Altitude Direct Strike Lightning Characterization program on January 30, 1985. Both meetings were chaired by Mr. David Albright, AVSCOM, St. Louis, MO.

Mr. Albright opened the meeting by welcoming all participants to St. Louis and hoping the next three days would be cooperative and productive.

The primary purpose of the meeting was to have the members of the NICG present an update to the project which were presented at the meeting in Norman, OK (March 27 and 28, 1984) and to discuss the future plans of their particular agency. Reviewing such plans allows for the transfer of information and in many cases, precludes redundant efforts.

BUSINESS:

Mr. David Albright opened the meeting by having the minutes of the last meeting read. Mr. Albright made a motion that the minutes be accepted as written. Mr. John Birken seconded the motion; motion passed.

Mr. Felix Pitts made a motion that Mr. Mike Glynn be nominated to fulfill the position of NICG secretary. Mr. Larry Walco seconded the motion; motion passed.

Mr. Nick Rasch made a motion that a letterhead for the NICG be developed and a working quantity be purchased. Mr. Rudy Bevin seconded the motion; motion passed.

Secretary needs to call Dr. Andy Revay, FIT, to determine if there are sufficient funds to purchase the letterhead.

DISCUSSION:

A committee meeting to discuss the conference committee status and plans for the 1985 and 1986 conferences was covered, and the following points brought up:

- The 1985 International Aerospace and Ground Conference on Lightning and Static Electricity which is sponsored by the NICG will be hosted by the French. The tentative time of the conference has been moved to the early part of June to coincide with the Paris Air Show.

- Mr. Andy Revay stated the balance of funds as of 12/31/84 was $25K with no more expenses.

- ORI has left the leftover 84 conference books.

- The August meeting will be in Dayton, Ohio in conjunction with the SAE4 and ADP meetings.

- Mr. Larry Walco needs a set of mailing labels (Mike Glynn will provide).

- Mr. Larry Walco will publish 86 proceedings.
- Paris conference - there appears to be a lot of phenomonology and very little "nuts and bolts" type papers.

- It was discussed as to whether we would initiate only certain type category subjects and then select the papers submitted. There were mixed emotions on this topic, it was dropped with no motion.

- It was suggested that possibly there could be a room with continuous movies/slides/tape, covering certain areas. No decision.

- Mr. Larry Walco asked who the Navy participant was: Mr. Bill Walker.
A LETTER OVERVIEW OF NATIONAL SEVERE STORM LABORATORY (NSSL) ACTIVITY AND SPRING OPERATIONS AND ANALYSIS (DR. V. MAZUR, NSSL, NOAA, NORMAN, OK)
Mr. Michael Glynn  
FAA Technical Center  
ACT-340  
Atlantic City Airport  
Atlantic City, New Jersey 08405  

Subject: Justification of the Convair-580 flights in 1986-87  

Dear Mike:  

I am happy to contribute to your efforts to justify using the Convair-580 airplane for studies of direct lightning strikes in the future.  

At the present time the major emphasis in investigations of lightning hazards to aircraft is made on in-flight data acquisition in electrically active thunderstorms. I think we are doing well in a sense of good statistics (especially for high altitude flights), but are lagging behind in scientific interpretation of direct lightning strike phenomena and of structures of storms where strikes occurred. From flights in thunderstorms we accumulated a valuable experience in both data acquisition technique and strategy and also learned a lot about types of strikes to aircraft. However, this work is not over yet.  

As we all know, thunderstorm penetrations are not avoidable only for military aircraft during their missions or for all types of aircraft during emergency takeoff and landing. The latter makes our studies of strikes at low altitude so important. The risk of strikes could be lessened if we know how to avoid potentially dangerous storm regions. In 1984 the NASA Storm Hazards Program collected some data which related together for each penetration the storm structure from ground radar observations, the airplane penetration patterns and locations of direct strikes, nearby flashes to aircraft and cloud-to-ground flashes. The purpose was to investigate on what stage of storm development and in what part of the storm the risk of being struck by lightning and by a cloud-to-ground flash is particularly the greatest. A potential application of such knowledge is obvious for air traffic control, which usually has good quality storm information around airport areas available in real time. Because of the need to have the statistically significant number of storm observations of the type described above, and the great difficulties of obtaining these data in a single season, it will be necessary to continue such observations after 1985 (when NASA program is in serious doubt) and maybe even later. This is a good task for the Convair-580 in the scheme of low altitude flights in summer thunderstorms.
A problem which requires immediate and serious attention from the aviation and scientific community is lightning hazards to aircraft in non-stormy precipitation clouds. The reasons are following:

1. Most of reported strikes to aircraft (80-90%) do not occur in active thunderstorms.

2. We have practically no knowledge of electromagnetic characteristics of these strikes that are all triggered flashes simply by definition of being in non-storm clouds. We can expect these strikes to be different than those in stormy clouds we have some experience with.

3. The data about strikes to aircraft in non-stormy clouds point to the freezing level as a region with the highest probability of strikes. I think we should consider this conclusion as only a preliminary one to start research with, because data were not obtained in a process of systematic and statistically sound study of non-stormy penetrations.

The issue of strikes in non-stormy clouds cannot be ignored any longer, because we are absolutely not ready to cope with potentially disastrous situations when the composite aircraft will fly in such common environment. I think we are waiting for a major catastrophe to wake us up.

In preparation of this letter, I discovered a memo from Don W. Clifford (McDonnell Aircraft Co.) to Felix Pitts (NASA Langley) dated 30 May, 1980, and addressing the need for study of the triggered strikes in non-stormy precipitation clouds. Don Clifford also had several ideas to implement, which I found interesting. Unfortunately, we are still at the same point in this research five years later.

The second major problem which was overlooked for a long time is lightning hazards to aircraft in winter storms. Soviet scientists report that the ratio of number of strikes to aircraft to the number of days with thunderstorms is much higher in winter than in summertime, and a peak season for strikes to aircraft in sea coastal areas of the USSR (Black Sea Coast) is during the winter months. Winter storm studies conducted in Japan and Northern Europe indicate that the absolute majority of cloud-to-ground strikes in these storms are positive CG flashes that carry continuous currents of significant values. Both peak and continuous currents of positive CG are much greater than those of negative CG that are most common in summer thunderstorms. Because of different structure of winter storms, they represent a different category of environment from the point of view of lightning hazards to aircraft, which should be investigated separately from non-stormy clouds and summer thunderstorms.

As we know, the 100 percent protection of the new generation aircraft from lightning strikes is unrealistic. Most visible would be a compromise solution of highest possible degree of protection and an avoidance of strikes. The latter requires studying environmental conditions and structures of storms in which direct strikes occur, as well as phenomenon of interaction between aircraft and cloud which results in strike initiation.

The FAA Convair-580 would be most suitable for long-time observations within both non-stormy precipitation clouds and winter storms.
June 3, 1985

The problem of lightning hazards to aircraft is a concern of the international aviation community. Nowadays, this community benefits from studies conducted in U.S.A. without significant financial contribution into the program. This creates an understandable desire to protect the interest of American industry from pirating ideas and results of investigations conducted on American funds. At the same time, funding for lightning research programs in U.S.A. is more difficult to obtain (example, your program and NASA's program) without, to my mind, completion of all major objects of research in this area. I propose to FAA, as the largest organization of its kind in the free world, to initiate an international program of study of lightning hazards to aviation. Funds can be pooled and then distributed to support scientists' work and data acquisition. The idea of an international program could be discussed first at the forthcoming NICG meeting, and if adopted, proposed to national organizations of different countries. The U.S.A contribution into this program could include aircraft (Convair-580 and possible F-106's) and ground support facilities.

I think that we should not procrastinate in this matter any longer. I would be happy to be of any additional help to you, Mike, in your efforts.

Sincerely,

Vladislav Mazur
Physicist

cc Norman Crabill, NASA Langley
Felix Pitts, NASA Langley
Maj. P.L. Rustan, Jr., Wright-Patterson AFB
AIR FORCE WRIGHT AERONAUTICAL LABORATORY (AFWAL) ACTIVITY FOR THE PAST YEAR (MR. L. WALKO, ATMOSPHERIC ELECTRICITY HAZARDS GROUP, WPAFB, OH)
ATMOSPHERIC ELECTRICITY HAZARDS

ASSESSMENT FOR AIRCRAFT

MAIN ACTIVITIES

1) Assessment Methodology - development of simulation techniques for assessment of the AEH Threat

2) Threat Characterization - measurement of the major parameters associated with Aircraft/Lightning interaction

3) Hardening Technology - testing of hardening options

ASSESSMENT METHODOLOGY

- Focused Effort in Work Unit 24020223
- Current Activities
  1) Fast Rise Time/High Current Generator Development
  2) New Portable Marx Design
  3) Expanded Computer Analysis Capability
  4) Comparison with Characterization Efforts
FAST RISETIME/HIGH CURRENT GENERATOR DEVELOPMENT

MILESTONES: DEMONSTRATION OF CAPABILITY

1) CYLINDER TESTS
   - Flight Line
   - 10 Shots
   - 36 kA RT = 180nSec (Max)

2) C-580 TEST
   - Flight Line
   - 67 Shots
     40 kA RT = 150nSec

3) F-16 TEST
   - Flight Line
   - 27 Shots
     40 kA RT = 130nSec

2-3
FAST RISETIME/HIGH CURRENT GENERATOR DEVELOPMENT

CURRENT ACTIVITIES
1) MODIFICATION OF PEAKING CAPACITOR
2) SET-UP ON GF-16 INDOORS
   a) DESIGN OF WHEEL STAND-OFFS
   b) REDesign OF RETURN PATH CONFIGURATION
3) REFINEMENT OF THE MODULAR RETURN PATH CONCEPT

NEW PORTABLE MARX

DIVISION FOCUSED ACTIVITY

CURRENT ACTIVITIES
1) PRELIMINARY ANALYSIS OF GENERATOR REQUIREMENTS
2) INITIAL ORDERING OF COMPONENTS
   a) HIPPOTRONIC POWER SUPPLY
   b) FIRST 15 CAPACITORS
   c) SECOND 25 CAPACITORS

NEW PORTABLE MARX

INITIAL DESIGN
1) 4 MILLION VOLTS TO BE OPERATED AT 3 MILLION VOLTS
2) 40 - 100KV CAPACITORS
3) 20 TRIGGERED SPARK GAPS
4) PORTABLE, MODULAR DESIGN

2-4
COMPUTER ANALYSIS

To correlate lightning simulation data with actual characterization data

To remove configuration effects from simulation data

To predict lightning/aircraft interaction effects

MILESTONES:

T3DFD implemented

1) Verified using previous NOAA C-130 data
2) Programmed for the C-580 aircraft

Preliminary analysis of a nose-to-tail strike

SIMULATION/CHARACTERIZATION COMPARISON

To compare simulation data with data from actual lightning strikes

To improve simulation techniques by adding computer analysis to the process

To assist in the calibration of the C-580 measurement sensors
Cl30 y-12 Plane

CV-580 V=10 Plane
Subtask II: Lightning Characterization

Objective - To obtain quantitative data on the electromagnetic parameters that characterize the lightning - aerospace vehicle interaction.

Current Activities: Lightning Characterization

- Coordination with NASA Kennedy Space Center to participate in FY85 Rocket Triggered Lightning Program at KSC in Summer 1985.
- Participation would involve use of AFWAL RTL cylinder, sensors and instrumentation.
- Participation by AFWAL personnel would be in advisory capacity.

Subtask III: Hardening Technology 24020223

Objective - Provide data to assist in the development of design guidelines for aircraft systems requiring hardening against the atmospheric electricity lightning hazard.

Specific Objectives - (1) Perform comparative tests on similar metal and graphite composite aircraft structures to assess lightning susceptibility.

(2) Develop fuel tank hardening concepts.
Subtask III: Hardening Technology 24020223

Activities:

1. Obtain composite forward fuselage F-16 mockup used in AH ADP Phase I.

2. Obtain GF-16 aircraft and set up in FIESL test area.

3. Monitor AFVAL/Navy fuel tank program (W.U. 24020247) and interpret results for possible in-house test program.

Subtask III: Hardening Technology 24020223

F-16 Composite Forward Fuselage/GF-16 Test Program

1. Develop test plan that will include magnetic field measurements and specific internal wire measurements.

2. If possible interchange fuselage panels from composite fuselage and GF-16 aircraft to obtain information on composite material shielding characteristics.
METHOD No.1

Screen - Modular Section

Individual Wires Spaced To One Meter

JGS 23 Jan 85

METHOD No.1

Circular Marks are Maintaining a One Meter Spacing

1 Meter

1/3 Meter

JGS 23 Jan 85

2-9
Method No.1 Quasi-Parallel Plate

Screen (on floor)

Tapered to Peaking Capacitor

Method No.2 Quasi-Parallel Plate

Loosely Strung Screen

Tapered, Ends

Screen Will Be 1 Meter from Landing Gear JGS 23 Jan 85
AFWAL/FIESL TECHNICAL PUBLICATIONS

TECHNICAL PAPERS:

ELECTROMAGNETIC MEASUREMENTS OF LIGHTNING ATTACHMENT WITH AIRCRAFT
P. RUSTAN
PRESENTED AT 1983 NICG LIGHTNING CONFERENCE, JUNE 1983

AIRBORNE MEASUREMENTS OF THE RISETIMES IN LIGHTNING RETURN STROKE FIELDS
P. RUSTAN, B. KUHLMAN, J. REAZER
PRESENTED AT 1983 NICG LIGHTNING CONFERENCE, JUNE 1983

ANALYSIS OF LIGHTNING CURRENT MEASUREMENTS
P. RUSTAN, P. AXUP
TO BE PRESENTED AT 1984 NICG LIGHTNING CONFERENCE, JUNE 1984

CHARACTERIZATION OF FAST RISE TIME ELECTROMAGNETIC PULSES RECORDED IN AIRBORNE MEASUREMENTS DURING FLORIDA THUNDERSTORMS
B. KUHLMAN, P. RUSTAN, J. REAZER
TO BE PRESENTED AT 1984 NICG LIGHTNING CONFERENCE, JUNE 1984

ROCKET TRIGGERED LIGHTNING - A COMPARISON WITH NATURAL LIGHTNING
R. RICHMOND
TO BE PRESENTED AT 1984 NICG LIGHTNING CONFERENCE, JUNE 1984

ATMOSPHERIC ELECTRICITY RESEARCH FOR AIRCRAFT INTERACTIONS
L. WALKO
TO BE PRESENTED AT 1984 CONFERENCE ON ELECTROSTATICS, JUNE 1984
TECHNICAL PAPERS

EFFECTS OF TOWERS AND LIGHTNING CURRENT MEASUREMENTS
P. RUSTAN AND B. MELANDER (BOEING CO.)
IEEE POWER APPARATUS TRANSACTIONS, SUBMITTED JUNE 1984

THE ROCKET TRIGGERED LIGHTNING PROGRAM: 1983 RESULTS
R. RICHMOND
TO BE PRESENTED AT NEM SYMPOSIUM, JULY 1984

AIRCRAFT MEASUREMENTS OF LIGHTNING CURRENTS AND FIELDS
P. RUSTAN, B. KUHLMAN
TO BE PRESENTED AT XX1st URSI GENERAL ASSEMBLY (INTERNATIONAL
UNION OF RADIO SCIENCE) AUGUST 1984

THE LIGHTNING THREAT TO AEROSPACE VEHICLES
P. RUSTAN
TO BE PRESENTED AT THE AIAA 23RD AEROSPACE SCIENCES MEETING
14-17 JANUARY 1985

AN UPDATE ON ATMOSPHERIC ELECTRICITY HAZARDS SIMULATION
TEST FACILITIES
L. WALKO, J. HEBERT
TO BE PRESENTED AT THE AIAA 23RD AEROSPACE SCIENCES MEETING
14-17 JANUARY 1985
AFNAL/FIESL TECHNICAL PUBLICATIONS

TECHNICAL REPORTS

IN HOUSE:
DATA ACQUISITION FOR EVALUATION OF AN AIRBORNE LIGHTNING DETECTION SYSTEM
L. Walko, J. Reazer
AFWAL-TR-83-3083, SEP 1983

1981 WC-130 LIGHTNING CHARACTERIZATION DATA REVIEW
B. Kuhlman, P. Rustan, J. Reazer
AFWAL-TR-84-3024, JULY 1984

CONTRACTOR:

AN EXPERIMENTAL AND THEORETICAL INVESTIGATION OF AN NEMP TYPE FAST RISE LIGHTNING SIMULATOR
J.D. Robb, LTRI
AFWAL-TR-84-3007, MARCH 1984
ATMOSPHERIC ELECTRICAL HAZARDS PROTECTION (AEHP) ADVANCED DEVELOPMENT PROGRAM (ADP) OVERVIEW (MR. R. BEAVIN, FLIGHT DYNAMICS LABORATORY, WPAFB, DAYTON, OH)
ATMOSPHERIC ELECTRICITY
HAZARDS PROTECTION

OBJECTIVE
- Demonstrate effective protection criteria for electrical / electronic sub-systems in advanced technology aircraft

APPROACH
- PHASE I
  - Develop balanced AEMP concepts
  - Provide cost effective, designed-in protection
- PHASE II
  - Demonstrate protection effectiveness
  - Design criteria

PAYOFF
- Reliable all-weather operation of advanced technology aircraft
- Protection qualification / assessment procedures
Phase II - Validation Test Approach

- Two ground testbed aircraft
  - F-14A fighter
  - YUH-61 helicopter
- Install operational test electronics, STE, and monitoring instrumentation
- Use identical special test equipment (STE) in each testbed
- Simulate lightning environments
  - Low level CW
  - Moderate level pulse
  - High level pulse
- Functionally monitor the operational electronics data including end function (lights, display, actuation)
- Monitor voltage and current conditions in wiring and components

Phase II - Protection Validation

**TASK XIV**
- RELIABILITY SYSTEM SAFETY AND DESIGN TO COST
  - Production of control RMM
  - System safety program
  - Generic lessons learned
  - Quality assurance design to cost

**TASK XIII**
- DESIGN CRITERIA AND GUIDES
  - Update internal design criteria from Task VI
  - Thermal summary
  - Composite predicted throat design test data for full range of flight vehicles

**TASK XII**
- QUALIFICATION TEST PROCEDURES
  - Qualification test procedures for AS and SRT systems

**TASK XI**
- TECHNOLOGY TRANSFER AND PROGRAM ARRANGEMENT
  - Industry briefing
  - Technical reviews and workshops

**TASK X**
- TEST VEHICLE PREPARATION
  - Transport, design and modification
  - Structural changes
  - Shielding enhancements
  - Cables and wire shielding

**TASK IX**
- PROTECTION EVALUATION
  - Simulation threat management
  - Test for response
  - Protection measures
Objectives

- Prepare installation design for the test equipment in the F-14A and the AEHP protection required for this equipment. Implement the modification and installation to prepare the F-14A for AEHP protection validation tests.

Approach

- Establish equipment to be installed, installation locations, wire bundle routes, and installation procedures.
- Prepare modification drawings and manufacturing plans to install the equipment and modify the F-14A.
- Coordinate the modification and subsequent refurbishment with the planning, manufacturing and quality assurance organizations.
Task X Protection Validation

OBJECTIVES:

- To determine the impact of AEH environments on flight and mission critical subsystems representative of new electronic technology and airframe structures (1990-1995 IOC)
- To obtain test data for use in validating the installed protection design approach by comparison of measured data to expected responses
- To obtain test data for use in validating the analytical tools and simulation test techniques used in the hardening design effort

APPROACH:

- Conduct the test with transfer function, moderate level pulse and high level pulse tests on ALCM flight control components and data bus equipment
- Measure external surface transient currents with metal panels for reference, then test with modified panels
- Measure open circuit transient voltages by means of special brass boxes in, FCSE and MRA. Also measure currents induced in the interconnecting cables of data bus equipment power and signal circuits
- Record the operational responses of flight controls and data bus equipment
Task X
Lightning Simulator Status

R.L. Solem
BMAC L-7170
206-241-4427
**Lightning Simulator**

**Objective:**
- To obtain the capability of producing a Zone 1A lightning strike simulation to support the indirect effects test on the F-14A.

**Approach:**
- Enter into subcontract with Maxwell Laboratories, Inc., directing them to build the lightning simulator.
- Confirm that the lightning simulator meets the specification.
- Coordinate Boeing Facilities and Maxwell Laboratories to provide a turn key system.

---

**Single Lightning Stroke Threat**

**AEHP SEVERE THREAT**
- MAXIMUM RISE RATE = 200 kA/s
- PEAK AMPLITUDE = 200 kA
- ENERGY INTEGRAL = $1.5 \times 10^8$ A²s
- RISE TIME 10 to 90% = 4 µs
- HALF TIME TO FALL = 60 µs

$$N_d = 2000 \cdot 14.3 \times 10^{-8} \cdot \phi^* \cdot 1.0 \times 10^8 \mu A$$

**AEHP MODERATE THREAT**
- MAXIMUM RISE RATE = 80 kA/s
- PEAK AMPLITUDE = 20 kA
- ENERGY INTEGRAL = $1.2 \times 10^6$ A²s
- RISE TIME 10 to 90% = 2 µs
- HALF TIME TO FALL = 50 µs

$$N_d = 20.06 \cdot 14.3 \times 10^{-8} \cdot \phi^* \cdot 2.5 \times 10^6 \mu A$$

![Graph showing Single Lightning Stroke Threat](image-url)
Lightning Simulator
Current Waveform Characteristics

\[ I(t) = I_m \left(1 - e^{-\frac{t}{\tau}}\right) \]

\[ I_m = 2 \times 10^{11} \text{A}, \quad \tau = 1 \times 10^6 \text{s} \]

\[ t_1 = 1.67 \times 10^{-6} = 1.67 \mu \text{s} \]

\[ t_2 = 1.12 \times 10^{-6} = 1.12 \mu \text{s} \]

\[ t_1 - t_2 = 0.5 \mu \text{s} \] (time from 10% to 90% of 200 kA)

\[ \frac{\text{MAXIMUM RATE OF RISE}}{\text{MAXIMUM CURRENT}} = \frac{I_0}{I_m} = 0.6 = 60\% \text{ of } 200,000 \text{kA} \]

High Energy Lightning Simulator

* 300 kA
* 2 x 10^6 A/s
* 600 kJ
F-14A Return Circuit Arrangement

Lightning Simulator
(Proposed Location)
Task IX

Vehicle Preparation
D. Walen
F. Hekel
Vehicle Preparation Progress

- Completed wire bundle and equipment installation drawings
- Started wire bundle fabrication
- Received Grumman graphite/epoxy overwing fairings and turtle deck panels
- Started wire bundle
- Started equipment mounting bracket fabrication
- Prepared ground support equipment connection design
Task X

Protection Evaluation - Test Planning

T. A. Prestwood
- TEST MATRIX COMPLETED
- TEST POINTS CHOSEN
- TEST EQUIPMENT DETERMINED
- TEST PROCEDURE ROUGH DRAFT
- PRELIMINARY TEST SCHEDULE PREPARED

---

F-14A Test Matrix – Nose-to-Tail

<table>
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<th>LEVEL 1 Vehicle Characteristics</th>
<th>CONFIGURATION 1</th>
<th>CONFIGURATION 2</th>
<th>CONFIGURATION 3</th>
<th>CONFIGURATION 4</th>
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<tbody>
<tr>
<td>+ DC Busbars</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>+ Load Introducer</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ Resistance Test</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>+ Surface Conduct</td>
<td>X</td>
<td>X</td>
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<tr>
<th>LEVEL 2 Actuator Transfer Response</th>
<th>CONFIGURATION 1</th>
<th>CONFIGURATION 2</th>
<th>CONFIGURATION 3</th>
<th>CONFIGURATION 4</th>
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<tr>
<td>+ Open Circuit Voltage</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>+ Cable Breakout</td>
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<td>X</td>
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<tr>
<th>LEVEL 3 Actuator Power Control Response</th>
<th>CONFIGURATION 1</th>
<th>CONFIGURATION 2</th>
<th>CONFIGURATION 3</th>
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<tr>
<td>+ Open Bus Equipment Response</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ ALCAS Equipment Response</td>
<td>X</td>
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<th>All Items Pouch Installed</th>
<th>Grille Turbo Data Pouch Installed</th>
<th>Turbo Data Pouch Removed</th>
<th>Grille Turbo Data Pouch Installed and Pumped Pouch Removed</th>
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<tr>
<td>CFI 30 kA</td>
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3-14
Transient Monitoring Setup

F-14A Test Matrix—Nose-to-Wingtip

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<th>TEST POINTS</th>
<th>CONFIGURATION 1</th>
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<tr>
<td>DC Resistance</td>
<td></td>
<td>Yes (in use)</td>
<td>Yes (in use)</td>
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<tr>
<td>Input Impedance</td>
<td></td>
<td>Yes (in use)</td>
<td>Yes (in use)</td>
</tr>
<tr>
<td>Grounded Voltage</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Surface Current</td>
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<td>DC Bus</td>
<td>Grounds</td>
<td></td>
<td>Yes (in use)</td>
</tr>
<tr>
<td>Cable Insulation</td>
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<td>Yes (in use)</td>
<td>Yes (in use)</td>
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3-15
DESIGN CRITERIA AND GUIDES
OUTLINE

I Introduction
II Definitions
III Program Requirements
IV Protection Methodology
V Environments
VI Aircraft Definition
VII Assessment Techniques
VIII Protection Schemes
IX Verification
X Life Cycle Concerns
XI References And Bibliography

PROGRESS

- Preliminary Outline Completed
- Inputs For F-14 Test Provided
- Initial Review And Sorting Of Data And Documentation Started

SCHEDULE

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TASK XVII
DIRECT EFFECTS
TASK XVIII - AEHP DIRECT EFFECTS PROTECTION

I. GOALS

A. DEFINE AND DEVELOP DESIGN GUIDELINES FOR
   1. INCORPORATION OF ELECTROMAGNETIC HAZARD PROTECTION INTO AIRFRAMES
   2. INCORPORATION OF DIRECT EFFECTS PROTECTION INTO AIRFRAMES

II. RESPONSIBILITIES

A. PROTECTION OF LOW RCS TECHNOLOGY (RAIN/RAS) - BOEING

B. REMAINING PROTECTION ACTIVITIES - LIGHTNING TECHNOLOGIES, INC., AND BOEING

SUMMARY

- SUBTASK I - IDENTIFY SPECIFIC PROBLEM AREAS - COMPLETED BY LTI OCTOBER 1, 1984
- SUBTASK II - STATE-OF-THE-ART REVIEW COMPLETED NOVEMBER 1, 1984
- SUBTASK III - IDENTIFY TECHNOLOGY NEEDS AND DEVELOP R & D PLANS OUTLINE SUBMITTED NOVEMBER 1, 1984. SUBTASK III WILL BE COMPLETED JANUARY 7, 1985
- SUBTASK IV - DIRECT EFFECTS ASSESSMENT TESTING BY BOEING THIRD QUARTER 1985
LIGHTNING PROTECTION STANDARD FOR MILITARY AIRCRAFT - AN OVERVIEW (AERONAUTICAL SYSTEM DIVISION WPAFB MR. L. WALKO, ATMOSPHERIC ELECTRICITY HAZARDS GROUP, WPAFB, OH)
LIGHTNING PROTECTION STANDARD FOR MILITARY AIRCRAFT

1978 - SAE AE-4L "BLUE BOOK" REPORT, "LIGHTNING TEST WAVEFORMS AND TECHNIQUES FOR AEROSPACE VEHICLES AND HARDWARE"
- 6 QUALIFICATION TESTS
- 3 ENGINEERING TESTS

1980 - MIL-STD-1757, "LIGHTNING QUALIFICATION TEST TECHNIQUES FOR AEROSPACE VEHICLES AND HARDWARE"
- 4 TEST METHODS FOR DIRECT EFFECTS
- 1 TEST METHOD FOR INDIRECT EFFECTS

1983 - MIL-STD-1757A
- APPLICATIONS GUIDANCE ADDED IN APPENDIX
- MINOR CHANGES/CORRECTIONS MADE

1986 - MIL-STD-XXXX, "LIGHTNING PROTECTION FOR AEROSPACE VEHICLES"
- LIGHTNING PROTECTION PLAN (LPP) AND DESIGN REQUIREMENTS
- LIGHTNING PROTECTION VERIFICATION PLAN (LPVP)
- LIGHTNING PROTECTION VERIFICATION REPORT (LPVR)

PLANNED - MIL-B-5087B REVISION
- TO INCLUDE ONLY ELECTRICAL BONDING REQUIREMENTS
- TO DELETE LIGHTNING PROTECTION REQUIREMENTS

AIRCRAFT LIGHTNING PROTECTION

- PRESENT AIRCRAFT (LARGELY METALLIC)
  - NO FUNDAMENTAL LIGHTNING DEFICIENCIES
  - OVERLOOKED AREAS FIXED THROUGH RETROFIT
  - ANY FUEL A POTENTIAL HAZARD
  - METAL FUEL TANKS CAN BE SPARK-FREE
  - RADOME PROTECTION NOT MANDATORY
  - CARBON FIBER COMPOSITES PRESENT DESIGN CHALLENGE
  - INDUCED EFFECTS PROBLEMS MINIMAL
  - FLY-BY-WIRE SYSTEMS PRESENT DESIGN CHALLENGE
  - RETROFITS/MODIFICATIONS MAY BE OVERLOOKED AREA
AIRCRAFT LIGHTNING PROTECTION (CONT'D)

- FUTURE AIRCRAFT (LARGELY COMPOSITE)
  - BONDING/GROUNDING TECHNIQUES NOT ADEQUATELY ESTABLISHED
  - COMPOSITE INTEGRAL FUEL TANKS IN R&D STAGE
  - COMBINED USE OF ANALYSIS/TESTING FOR VERIFICATION TO INCREASE
  - INDUCED VOLTAGE/CURRENT LEVELS MAY EXCEED INTERFACE LIMITS
  - REVISED TEST METHODS NEEDED FOR DIGITAL UPSET/DAMAGE MECHANISMS
  - NEW ADVANCED MATERIALS NOT YET ADEQUATELY ASSESSED
  - CORROSION CONTROL/ELECTRICAL BONDING MAY BE INCOMPATIBLE
  - LOW CROSS-SECTIONAL/ABSORBING MATERIALS NOT YET ASSESSED
  - IMPROVED PERFORMANCE TESTS AND VERIFICATION TECHNIQUES NEEDED
  - REPAIR/MAINTENANCE TECHNIQUES NEED TO BE DEVELOPED
  - NON-DESTRUCTIVE TESTS FOR WEAK LINKS NEED TO BE DEVELOPED
  - CUMULATIVE EFFECTS NEED TO BE ASSESSED

NEW APPROACHES TO AIRCRAFT LIGHTNING PROTECTION

- NEED TO CONSIDER
  - PROBABILITY OF STRIKE OCCURRENCE
  - AIRCRAFT MISSION
  - COST OF PROTECTION
  - AIRCRAFT SAFETY
  - WEIGHT PENALTY
  - REPAIR/MAINTENANCE
  - SUSCEPTIBILITY/VULNERABILITY OF AIRCRAFT EQUIPMENT/SYSTEMS
  - RISK/PENALTY TRADEOFFS
  - ELECTRONICALLY-CONTROLLED FLIGHT-ESSENTIAL SYSTEMS
  - LIGHTNING THREAT LEVELS/RATES OF RISE
  - LIGHTNING WARNING SYSTEMS
US ARMY PROGRAM FOR PROTECTION OF AIRCRAFT AGAINST NATURAL EM HAZARDS, A PROGRESS REVIEW (MR. D. ALBRIGHT, AVSCOM, ST. LOUIS, MO)
1. Overview.

a. Today I'm going to discuss some of the past year's activities in specifying design requirements for protection of U.S. Army aircraft, most notably helicopters, against such natural hazards as lightning strikes and electrostatic discharges as well as requirements for analysis and tests to demonstrate that such protection has been provided. Tomorrow I'll address lessons learned, needs, and some activities for the coming year. One interesting highlight of the past year was the lightning strike of a UH-60A (BLACK HAWK) helicopter during flight over Germany. I'll say a few words about that.

b. Most of what I have to say pertains to activities with which I have been directly involved at HQ, U.S. Army Aviation Systems Command (AVSCOM) in St. Louis. Tomorrow's presentation will include some details of the ongoing Advanced Composite Aircraft Program (ACAP) which is being directed by AVSCOM's Applied Technology Laboratory out of Ft Eustis, VA.

2. Background.

a. To repeat what I have stated in the past, the Directorate for Engineering is primarily a regulatory agency in that we specify design and test requirements to produce military qualified flightworthy aircraft systems. We participate in design reviews, review test plans, witness tests, and review test reports. We also provide engineering support for fielded systems.

b. Technology research is conducted by our various laboratories which are located elsewhere around the country.

3. Current Activities.

Protection against lightning and static electricity hazards is a specific part of the following programs:

a. The Air-to-Air STINGER missile weapon system which is being designed for use on OH-58C/D scout helicopters.

b. The Volcano mine dispensing system which is being designed for use on UH-60 utility helicopters.

c. A 230-gallon filament wound external fuel tank which is being designed for use on UH-60A, AH-64A (APACHE), and HH-60D (Air Force Night Hawk) helicopters.

d. The Mast Mounted Sight portion of the OH-58D scout helicopter.

e. A composite rear fuselage (transition section) which is being designed to replace the aluminum one on the UH-60 and HH-60D helicopters.


a. One of the problems here has been the one of selling the requirement to protect against lightning strike hazards while the basic aircraft themselves have not specifically been lightning hardened.
b. As a compromise, the minimum requirement agreed to has been to preclude inadvertent detonation, launch or jettison of the weapon for a direct strike in both the parked and airborne conditions.

c. Emphasis has been placed on analysis of direct and induced effects while the requirement to test has not been ruled out.

d. An upcoming meeting between one of the contractors, their consultant, Lightning and Transients Research Institute, and the Army will address lightning test requirements for the Volcano mine dispensing system which might involve the use of a simulated aircraft fuselage. Testing of the STINGER installation is not yet certain.

e. Some testing has already been conducted on some of the basic weapon system components but for ground-use hazards only. The airborne application poses additional hazards such as direct lightning strikes and higher static charge potentials.

f. The static discharge hazard of 25,000 volts due to personnel handling is fairly acceptable; however, the 300,000 volt hazard associated with a hovering aircraft is not only overly stringent for smaller aircraft, it is also a less obvious hazard.

5. 230-Gallon External Fuel Tank.

a. This is a filament-wound fuel tank with nomex honeycomb core, inner layers of Kevlar and glass, outer layers of interwoven graphite and Kevlar, and a plastic liner. The Army and Air Force configurations differ only in plumbing and controls. Fibertek is the manufacturer.

b. Lightning and static charge tests were completed late last year at Lightning and Transients Research Institute.

c. Bonding measurements were made between all metal parts and ranged from 4 to 55 ohms.

d. Resistance and capacitance measurements were made between various points on the inner liner and the grounding jack for estimates of charge relaxation times. Values of RC time constant of the order of seconds were obtained.

e. The inner liner was also charged to various voltage levels up to a maximum of 30KV, the source removed, and the charge level monitored with time. Decay times of 20 seconds or less were measured. Earlier experiments involved charging to 150KV and slower discharges were evident which was postulated as being due to overstressing the plastic liner.

f. Lightning testing began with induced effects (high di/dt) measurements on wiring entering the tank. The wire outside the tank was initially unshielded. An induced voltage of 800 volts was measured, which reduced to 55 volts after shielding was added.

g. The last test involved the application of high current strikes to the graphite shell itself as well as to various metal parts penetrating the surface.
h. All strikes to the graphite resulted in relatively superficial damage such as burnt paint, torn surface fibers, and some surface delamination. No structural damage occurred.

i. The only metal parts exhibiting damage were the vent valves and the metal ring surrounding the filler cap. The only internal sparking occurred at the drain plug which is spring-loaded.

6. **Mast Mounted Sight (MMS).**

   a. The mast mounted sight subsystem, which was designed by McDonnell Douglas Astronautics Co. out of Huntington Beach, CA, is a spherical package housing a FLIR, TV, and laser rangefinder/designator, which rotates on a pedestal, all of which is mounted atop the mast of an OH-58D helicopter. Both sphere and pedestal are made of carbon epoxy, which is covered with aluminum tape using a conductive adhesive.

   b. Lightning tests were conducted late last year by Douglas Aircraft.

   c. High voltage attachment tests were performed which resulted in attachment to the nearest point on the sphere, minor pitting of paint and no internal arcing.

   d. Induced effects (high di/dt) measurements were made on internal wiring with the maximum voltage being 25 volts, which when extrapolated (appears to be aperture coupling) computed to be 125 volts. Even if diffusion coupling were assumed the voltage would compute to be 200. A pass/fail criterion of 500 volts was used. There was no internal arcing.

   e. Finally, a high current strike was applied which resulted in some peeling of tape and subsequent burning of same (components B and C). A maximum voltage of 450 was measured which appeared to be diffusion coupled.

   f. An earlier version of MMS was tested which was covered by aluminum flame spray (partial on pedestal). One instance of internal sparking and some large aperture coupling was observed prior to incorporation of some additional insulation and 100 percent flame spraying of the pedestal.

7. **Composite Rear Fuselage (CRF).**

   a. This involves replacing the aluminum transition fuselage section (skin and stringers) between the main cabin and the tailcone of the UH-60A (and HH-60D). The skin of the CRF is comprised mostly of Kevlar panels covered with aluminum screen mesh. Some graphite and aluminum panels are also used. Sikorsky Aircraft is the contractor.

   b. Sikorsky did extensive testing of panels and joints for conduction of lightning currents and shielding effectiveness prior to selection of the final design. Much of this work was done earlier in conjunction with the ACAP program. No additional lightning testing is planned; although some avionics tests are planned which includes measurements of any increased noise level due to static discharges.

   c. Emphasis is being placed on producibility, repairability, and maintainability. Attempts are being made to also include tracking of the quality of electrical bonding with time.
8. **Lightning Strike of UH-60A.**

a. The reason why any lightning strike of an Army helicopter is so noteworthy is that only four airborne strikes have been recorded since 1970. The latest occurred on 11 May 1984 and involved a UH-60A flying over Germany and under the following conditions: IFR in the clouds, at 7000 feet, and during very light icing conditions.

b. The crew reported a loud bang and a bright flash; several warning horns sounded and a number of caution and warning lights came on. Not knowing the extent of damage, the crew reduced rotor system loading, retarded engine controls, and accordingly put the aircraft into autorotation. The aircraft broke out of the clouds at 6500 feet and powered control was resumed at 800 feet. The crew flew a short distance and landed with no further damage. There were no injuries.

c. Several Sikorsky engineers were dispatched to Germany to interview the pilots and obtain damage information first hand.

d. Preliminary results of their findings are as follows:

(1) This appeared to be a cloud-to-cloud discharge with physical damage being concentrated in the main and tail rotor systems. No damage evident in the landing gear.

(2) Although the electrical power system remained operational, the use of various subsystems was lost.

(3) Most of the damage observed was predictable; except for the tail rotor blade, which sustained damage more extensive than that observed during any worst case lightning testing.

(4) The lightning current path was tracked between one tail rotor blade and one main rotor blade via blade linkages, gear boxes, and drive trains. Tracing of the path was facilitated by evidence of residual magnetism, arc burns, melting and pitting. The other blades were essentially undamaged.

(5) The primary visible damage was to the one tail rotor blade where the outer 18 inches of honeycombed trailing edge was missing. Much of the damage may have occurred after the strike due to airloads.

(6) The current plan is to have selected mechanical, electrical, hydraulic, avionic, and AFCS components sent to Sikorsky for a detailed tear-down analysis. The lightning damaged aircraft is currently located at Scott Air Force Base in Illinois awaiting further disposition.

9. I'll continue to report on activities such as these as well as provide whatever account I can of actual lightning strikes to Army aircraft.
DESIGN GUIDE FOR LIGHTNING PROTECTION OF ADVANCED FUEL SYSTEMS
- A PROGRESS REVIEW (NAVAL AIR DEVELOPMENT CENTER,
MR. D. SNEDAKER, LAKEHURST, NJ)
AIRCRAFT FUEL SYSTEM
LIGHTNING PROTECTION DESIGN AND QUALIFICATION
TEST PROCEDURES DEVELOPMENT

PROGRAM PLAN

BY
LIGHTNING TECHNOLOGIES, INC.

PREPARED FOR
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PENNSYLVANIA

CONTRACT N62269-83-C-0066
PROGRAM OBJECTIVES

DEVELOP AND VERIFY A SET OF DESIGN AND QUALIFICATION TEST PROCEDURES FOR THE VALIDATION OF AIRCRAFT FUEL SYSTEM PROTECTION

PRIME CONTRACTOR
LIGHTNING TECHNOLOGIES, INC.
K.E. CROUCH, PRINCIPAL INVESTIGATOR

SUB-CONTRACTOR
LIGHTNING & TRANSIENTS RESEARCH INSTITUTE
J.D. ROBB, PRINCIPAL INVESTIGATOR

APPROACH

PHASE I - STATE-OF-THE-ART REVIEW
PHASE II - REVIEW OF BASIC MINIMUM IGNITION
PHASE III - DEVELOPMENT OF PROCEDURES AND CRITERIA
PHASE IV - EVALUATION AND DEMONSTRATION OF PROPOSED PROCEDURES AND CRITERIA
PHASE V - PUBLICATION OF TEST PROCEDURES AND CRITERIA SPECIFICATIONS
PHASE I

REVIEW OF PRESENT TEST PROCEDURE AND CRITERIA

OBJECTIVE

DETERMINE PRESENT STATE-OF-THE-ART OF LIGHTNING TEST PROCEDURES AND PASS/FAIL CRITERIA FOR AIRCRAFT FUEL SYSTEMS

APPROACH

- MANUFACTURERS/AGENCY SURVEY
- REVIEW OF SPECIFICATIONS
  - MIL-STD-1757A
  - FAA AC 20-53A
  - AFWAL AEHP
- DETERMINE BASELINE CRITERIA
  - ALUMINUM CONSTRUCTION
  - 200 MICROJOULE SPARK
  - PROPANE/AIR DETECTION TECHNIQUE
  - PHOTOGRAPHIC DETECTION TECHNIQUE
  - MARGIN OF SAFETY/ERROR CONSIDERATIONS
PHASE I

PASS/FAIL CRITERIA

APPROACH
- LITERATURE SEARCH
- USER COMMENTS
- TEST EXPERIENCE

FINDINGS
- FUEL/AIR MIXTURES (PROPANE)
  - LOTS OF SPARK STUDY DATA
    - LEWIS AND VON ELBE
    - BARRETT
  - VERY LITTLE WORK ON
    - HOT SPOTS
    - HOT PARTICLES
    - CORONA
  - 0.2 MJ REPRESENTS LOWER LIMIT
    - 1-10% OCCURRENCE LEVEL
  - NO FORMAL DEVELOPMENT STUDY
- PHOTOGRAPHIC TECHNIQUE
  - DEVELOPED TO AVOID EXPLOSIVE TESTING
  - NO FORMAL DEVELOPMENT STUDY
  - THEORY GOOD-IMPLEMENTATION VERY DIFFICULT
  - NOT USEFUL WITH TRANSLUCENT SAMPLES
PHASE I

FINDINGS (WORK COMPLETED NOVEMBER 1984)

- THREAT DEFINITIONS ADEQUATE
- PROCEDURES ADEQUATE
- PASS/FAIL CRITERIA INADEQUATE
- MARGIN OF SAFETY/ERROR ASSESSMENTS NOT POSSIBLE
PHASE II

REVIEW AND ESTABLISHMENT OF BASIC MINIMUM IGNITION CRITERIA

OBJECTIVE

DETERMINE AND ESTABLISH MINIMUM IGNITION LEVELS FOR HYDROCARBON CONSTITUENTS OF AIRCRAFT FUELS IN A RESEARCH LABORATORY ENVIRONMENT

APPROACH

- REVIEW OF SPARK IGNITION STUDIES
- REPEAT SPARK IGNITION LEVEL EXPERIMENTS
- PERFORM RESEARCH INTO IGNITION BY:
  - ARC PLASMA
  - HOT PARTICLES
  - HOT SPOTS
  - CORONA
- DETERMINE STATISTICAL RELATIONSHIPS
- CONSIDER EFFECTS OF:
  - INITIAL TEMPERATURE
  - ELECTRODE MATERIALS
  - OXYGEN CONTENT
  - FUEL TYPES
  - AREA (HOT SPOTS)
PHASE II

PROGRESS  (25% COMPLETED AS OF JANUARY 1, 1985)

- VACUUM CHAMBER TEST BED SYSTEM ESTABLISHED
- PROPANE/AIR SPARK IGNITION DATA TAKEN
  - 200 MICROJOULE IGNITION PROBABILITY
    BETWEEN 1/100 AND 1/1000 (PRELIMINARY)
- OXYGEN RICH PROPANE SPARK TESTS UNDER WAY
  - INCREASE O_2 SIGNIFICANTLY REDUCES IGNITION ENERGY
- PENTANE, ETHENE, ETHYNE/AIR SPARK TEST PLANNED
- ARC, PARTICLE, HOT SPOT AND CORONA WORK TO FOLLOW
- TIME AND FUNDING LIMITATIONS MAY REQUIRE OMISSION
  OF SOME ASPECTS
PHASE III

DEVELOPMENT OF TEST PROCEDURES AND PASS/FAIL DETECTION CRITERIA

OBJECTIVE

DEVELOPMENT OF METHODS AND CRITERIA FOR DETECTING IGNITION SOURCES QUANTIFIED IN PHASE II, PROPOSED PROCEDURES AND CRITERIA WILL BE PUBLISHED

APPROACH

REPRODUCE MINIMUM IGNITION LEVELS IN LIGHTNING LABORATORY REPRESENTATIVE ENVIRONMENTS AND DEVELOP METHODS OF DETECTING THE IGNITION SOURCE

- DEVELOP LIGHT TIGHT BOX
- EVALUATE DETECTION METHODS
  - FUEL/AIR
  - PHOTOGRAPHIC
  - TEMPERATURE SENSORS
  - PHOTO MULTIPLIERS
  - FIBER OPTICS
- IGNITION SOURCES
  - SPARKS
  - ARCS
  - PARTICLES
  - HOT SPOTS
PHASE IV

EVALUATION AND DEMONSTRATION OF PROPOSED AIRCRAFT FUEL SYSTEM TEST PROCEDURES AND PASS/FAIL DETECTION CRITERIA

OBJECTIVE

THE TEST PROCEDURES AND PASS/FAIL DETECTION CRITERIA DEVELOPED IN PHASE III WILL BE DEMONSTRATED AND EVALUATED BY SEVERAL OF THE POTENTIAL LABORATORY USERS DURING THIS PHASE

APPROACH

• INDUSTRIAL REVIEW
  • SAE AE4L COMMITTEE COMMENTS
• DEMONSTRATION OF TECHNIQUES BY TESTS
  • LTI
  • LTRI
• USER EVALUATION ROUND ROBIN TESTS
  • MCDONNELL
  • BOEING
  • LTI
  • LTRI
PHASE V

DOCUMENTATION OF RESULTS AND PUBLICATION OF AIRCRAFT FUEL SYSTEM LIGHTNING PROTECTION DESIGN AND QUALIFICATION TEST SPECIFICATION

OBJECTIVE

PUBLICATION OF THE TEST SPECIFICATION WITH PASS/FAIL CRITERIA AND THE REPORT SUBSTANTIATING THE BASIS FOR ITS ADOPTION ALONG WITH GUIDELINES FOR USE INCLUDING MARGIN OF SAFETY ASSESSMENTS

APPROACH

RESULTS OF PREVIOUS PHASES WILL BE INCORPORATED INTO THE FINAL DOCUMENT WITH RETEST VERIFICATIONS PERFORMED AS NEEDED
NAVY BASIC RESEARCH PROGRAM ON LIGHTNING - AN OVERVIEW (DR. L. H. RUHNKE, NAVAL RESEARCH LABORATORY, WASHINGTON, DC)
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<td>PROTECTION RULES FOR PEOPLE</td>
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**1750 TO 1780**

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**1920 TO 1930**

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**1940 TO 1950**

7-2
### 1975 TO 1985

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<td>THUNDERSTORM MEASUREMENTS</td>
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**Chief of Naval Research**

**Naval Research Lab. (NRL)**  
In-house research

**Office of Naval Research (ONR)**  
Contract research

Past substantial support on lightning research by ONR:

- New Mexico Inst. Mining & Tech.  
  (Wormser, Brook, Moore)
- SUNY, Albany  
  (Vonnegut, Orville)
- Univ. Arizona  
  (Krieger)
- Univ. Florida  
  (Suman)
- Rice Univ. (Few)
- Univ. Minnesota  
  (Freier)
First Return Strokes

Serhan et al. (1980)

Weidman et al. (1981)

$1/f$

$1/f^2$

Spectral Amplitude (dB)

Frequency (Hz)

Current Derivative (kA/µs)

Percent

Present Study

Carabagnati 55

Berger 55

Carabagnati First 45

Berger First 45

99.8
99.6
99.4
99.2
99.0
98.8
98.6
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3.0
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2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0 1 2 5 10 20 50 100 200 500

Current Derivative (kA/µs)
LIGHTNING INITIATION ALTITUDES

STORMS IN NEW MEXICO

STORMS IN FLORIDA

WINTER STORMS IN JAPAN

Potential Gradient Over Top of Cumulus
At 2220 m Altitude

Grad V

2 volts cm⁻²

SPACE CHARGE (elementary charges cm⁻³)

DISTANCE (km)

0 5

0952 CST

Airplane Path Beneath Cloud Bases After First Pass Through Cloud

1011 CST

Space Charge Observed Beneath Bases of Clouds Growing Over Negative Charge Source

1020 CST

1024 CST

1027 CST

First Pass By Plane Was Through Cloud

Later Passes Just Beneath Cloud

Positive Charge Observed Beneath Edges of Cloud

Line Source of Negative Charge

Updraft
GNN presently supports:

SUNY: Barreto
     Kim
     Vonnegut

NMIM&T: Moore
       Brook

U. Minn.: Olson

R.D. Hill, Inc.
ATMOSPHERICS RANGING PROBLEMS

WALDORF ANNEX

4200 KM

OBSERVED LOCATION

ELECTRIC FIELD at 4000'

TIME (seconds)

FIELD (V/m nominal)

23 NOVEMBER '83

7-8
TRIGGERED OR NATURAL LIGHTNING?

1) Strike Probabilities Very Different
2) Strike Energies and Currents Very Different
3) Consistency of Necessary Conditions Very Different

- Downward Propagating Natural Discharge
- Upward Propagating Triggered Discharge

Aircraft Necessary Sphere of 'Attraction'

Necessary Field and Plane-Charge Conditions

Continuation of Discharge beyond Aircraft

Downward Propagating Triggered Discharge
SUMMARY: PRACTICAL RESULTS

1) Strike Probabilities under Various Conditions
   (Avoidance and Regulation)

2) Strike Intensity Distribution
   (Hardening and Regulation)

3) Necessary Conditions for (Triggered) Strike
   (Warning and Regulation)

THE CASE FOR TRIGGERING

1) Aircraft Strikes More Frequent in Flight
2) Measured Currents Lower than Expected
3) Large Conducting Objects Should Trigger
LOCATION OF ELECTROMAGNETIC SENSORS ON THE F-106B

1 = STRIKE CURRENT
D = ELECTRIC FLUX DENSITY
B = MAGNETIC FLUX DENSITY

- I SENSORS (3)
- D SENSORS (2)
- D SENSOR
- D AND B SENSORS (EACH WING)
- INDUCED TRANSIENT WIRES (3)

LIGHTNING INSTRUMENTATION

Transient recorders
12 channels

Fiber optic control link encoder/decoder

Motor
Generator

Instrumentation recorders
Buffer amplifiers
NAVAL AIR SYSTEMS COMMAND ACTIVITIES

A PROGRESS REVIEW*

(MR. J. BIRKEN, NAVAIRSYSCOM, WASHINGTON, DC)

*Presentation not submitted for inclusion into the minutes
SUMMARY OF NASA LaRC LIGHTNING CHARACTERIZATION AND EFFECTS
(MR. F. PITTS, NASA-LANGLEY RESEARCH CENTER, HAMPTON, VA)
LIGHTNING CHARACTERIZATION AND EFFECTS

Felix L. Pitts

NASA Langley Research Center
LIGHTNING CHARACTERIZATION

- Summarize acquired data
- Review statistical data analysis
- Assess completeness of high altitude data set
- Review data interpretation
- Coordination summary
- Summary and plans

LIGHTNING CHARACTERIZATION AND EFFECTS

- Objective
  Develop techniques for assessing digital system performance in the lightning environment aboard aircraft
  - Collecting in SITU direct-strike data using F-106B
  - Developing lightning and aircraft interaction models for use in data interpretation
  - Conducting analytical and laboratory digital system upset investigations
STRIKE SUMMARY VERSUS ALTITUDE

Total strikes = 627
1984 data

Pressure altitude, ft

Penetrations

Strikes

Strikes/penetration

VERTICAL FIN CURRENT
( DC-400 Hz )

Transient recorder trigger

80 amps

0.1 sec

80 amps

80 amps

9–4
RANGE OF CHANGE OF ELECTRIC FLUX DENSITY

\[ \dot{D}_F, \quad A/m^2 \]

NOSE BOOM CURRENT

\[ I_{n'}, \quad \text{amps} \]
ELECTROMAGNETIC SIGN CONVENTION AND SENSOR LOCATION

TOTAL DATA BASE THROUGH 1984

- 627 strikes/2171 transients

<table>
<thead>
<tr>
<th>Year</th>
<th>B_L</th>
<th>D_F</th>
<th>I_B</th>
<th>I_B</th>
<th>B_T</th>
<th>D_T</th>
<th>D_WL</th>
<th>D_WR</th>
<th>B_WL</th>
<th>D_WR</th>
<th>B_WR</th>
<th>I_VF</th>
<th>V_FW</th>
<th>V_FW</th>
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<tr>
<td>1982 and prior</td>
<td>46</td>
<td>93</td>
<td>27</td>
<td>8</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>166</td>
<td>216</td>
<td>17</td>
<td>56</td>
<td>23</td>
<td>56</td>
<td>24</td>
<td>15</td>
<td>16</td>
<td>34</td>
<td>48</td>
<td>39</td>
<td>5</td>
<td>24</td>
</tr>
<tr>
<td>1984</td>
<td>119</td>
<td>117</td>
<td>105</td>
<td>120</td>
<td>126</td>
<td>125</td>
<td>105</td>
<td>91</td>
<td>43</td>
<td>37</td>
<td>120</td>
<td>74</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>Total waveforms</td>
<td>331</td>
<td>117</td>
<td>414</td>
<td>164</td>
<td>190</td>
<td>23</td>
<td>181</td>
<td>129</td>
<td>15</td>
<td>16</td>
<td>77</td>
<td>85</td>
<td>159</td>
<td>79</td>
</tr>
<tr>
<td>370 strikes, 94 peaks (strikes)</td>
<td>46</td>
<td>45</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

- 370 strikes, 94 peaks (strikes)

9-8
STATISTICAL ANALYSIS SUMMARY

• Statistical analysis of direct strike lightning data (1980 to 1982)
  NASA TP 2252

• Probability plotting method and formal statistical test
  used to check adequacy of log normal and type II
  extreme value models
• Robust estimation method used to compute quantile estimates
  (Quantile estimates valid without assumption of parametric
  models)
• Approximate confidence limits are determined for the
  quantiles
• Tables constructed showing how the sample size depends
  on the precision of the estimates.

STATISTICAL CHARACTERIZATION OF LIGHTNING DATA
SAMPLE SIZE
VERSUS PRECISION FOR 95% CONFIDENCE LEVEL

Data samples through 1982
( ) Data samples through 1984

<table>
<thead>
<tr>
<th>Quantile</th>
<th>U/L ratio</th>
<th>N(δS)</th>
<th>N(δS)</th>
<th>N(t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.99</td>
<td>1.5</td>
<td>592</td>
<td>421</td>
<td>222</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(331)</td>
<td>(414)</td>
<td>(164)</td>
</tr>
<tr>
<td>2.0</td>
<td>202</td>
<td>144</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>116</td>
<td>82</td>
<td>43</td>
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</tr>
<tr>
<td>3.0</td>
<td>81</td>
<td>57</td>
<td>30</td>
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</tr>
<tr>
<td>.95</td>
<td>1.5</td>
<td>188</td>
<td>134</td>
<td>70</td>
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<tr>
<td></td>
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<td></td>
<td>27</td>
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<tr>
<td>2.0</td>
<td>64</td>
<td>46</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>37</td>
<td>26</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>26</td>
<td>18</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

DATA ASSESSMENT

High altitude

- Assuming 82 and prior distribution families hold
- Can estimate 99th quantiles with 95% U/L confidence ratios:
  
<table>
<thead>
<tr>
<th></th>
<th>1982</th>
<th>1983</th>
<th>1984</th>
</tr>
</thead>
<tbody>
<tr>
<td>δ</td>
<td>--</td>
<td>2.0</td>
<td>1.75</td>
</tr>
<tr>
<td>δ</td>
<td>2.5</td>
<td>1.7</td>
<td>1.5</td>
</tr>
<tr>
<td>I</td>
<td>--</td>
<td>2.5</td>
<td>1.75</td>
</tr>
</tbody>
</table>

- Have 190 δ waveforms and 45 peaks to establish δ distribution
- Precision for smaller samples can be estimated from table
DATA ASSESSMENT

Low altitude

- Need 50 to 100 samples to test adequacy of usual distribution models
- Example:
  Requires 100 samples to reject lognormal when true is extreme value

<table>
<thead>
<tr>
<th>Sample size</th>
<th>20</th>
<th>50</th>
<th>100</th>
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</thead>
<tbody>
<tr>
<td>Probability of rejecting log normal</td>
<td>31</td>
<td>63</td>
<td>93</td>
</tr>
</tbody>
</table>
PEAK RECORDED VALUES

ELECTRIC FLUX DENSITY RATE
75 ampere per square meter

CURRENT RATE
1.9 E10 ampere per second

CURRENT
54 kiloampere

LIGHTNING THREAT CRITERIA

<table>
<thead>
<tr>
<th></th>
<th>Peak current</th>
<th>Max current rise rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old criteria:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAE AE-4L (1978)</td>
<td>200 kA</td>
<td>100 kA/μs</td>
</tr>
<tr>
<td>MIL B-5087 (1978)</td>
<td>200 kA</td>
<td>100 kA/μs</td>
</tr>
<tr>
<td>JSC-07636-Shuttle (1975)</td>
<td>200 kA</td>
<td>100 kA/μs</td>
</tr>
<tr>
<td>NASA F-1068 finding: (1983)</td>
<td>14 kA</td>
<td>190 kA/μs</td>
</tr>
<tr>
<td>(1984)</td>
<td>54 kA</td>
<td></td>
</tr>
<tr>
<td>New criteria:</td>
<td></td>
<td></td>
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<tr>
<td>Boeing AEHP (1984)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud-cloud: Severe</td>
<td>20 kA</td>
<td>200 kA/μs</td>
</tr>
<tr>
<td>Moderate</td>
<td>5 kA</td>
<td>50 kA/μs</td>
</tr>
<tr>
<td>Cloud-ground: Severe</td>
<td>200 kA</td>
<td>200 kA/μs</td>
</tr>
<tr>
<td>Moderate</td>
<td>20 kA</td>
<td>50 kA/μs</td>
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</tbody>
</table>
LIGHTNING EFFECTS
ON AIRCRAFT DIGITAL ELECTRONICS

Data analysis objective
Methodology to predict transients in generic composite aircraft systems for use in upset assessment studies

DATA INTERPRETATION - GENERAL PROBLEM
- F-106 data specific to F-106, i.e., are responses
- Require characterization of generic lightning processes applicable to composites/transports

- Approach:
  - Computer modeling (EMA)
  - Laboratory modeling (Texas Tech)
  - Simple analytical models (LuTech)

- Status:
  - Methodology not completely established - some progress/problems
    - Natural lightning/linear modeling
    - Channel model parameters and uniqueness issues
    - Triggered lightning/non-linear modeling
      - Air breakdown model shows promise
ELECTROMAGNETIC COUPLING CODE F - 106 MODEL

Solves Maxwell's PDE as system of FDE

NONLINEAR DATA INTERPRETATION METHODOLOGY

\[ \nabla \times E = -B \]
\[ \nabla \times H = \sigma E \]
\[ \sigma = q \left[ n_e \mu_e + (n_- + n_+) \mu_1 \right] \]
\[ \frac{\partial n_e}{\partial t} + \nabla \cdot (n_e \mu_e E) + \beta n_+ + a_e - G \cdot n_e = \dot{Q} \]
\[ \frac{\partial n_-}{\partial t} + \nabla \cdot (n_- \mu_{l} E) + \delta n_+ n_- = a_e n_e \]
\[ \frac{\partial n_+}{\partial t} + \nabla \cdot (n_+ \mu_1 E) + (\beta n_e + \delta n_-) n_+ = \dot{Q} + G n_e \]
TRIGGERED LIGHTNING NONLINEAR MODEL RESULTS VERSUS FLIGHT DATA

E = 1 \times 10^5 \text{ V/m} \quad \text{NOSE TO TAIL} \quad q = -Qm/2

MODEL RESULTS

FLIGHT DATA

PARAMETERS IN DATA INTERPRETATION METHODOLOGY

q = \text{Charge in electron} \quad \beta = \text{Recombination rate (e - i)}

n_e, n_i, n_+ = \text{Electron and ion densities} \quad \delta = \text{Recombination rate (i - i)}

\mu_e, \mu_i = \text{Electron and ion Mobilities} \quad \sigma_e = \text{Attachment rate - } f_1(E)

\dot{Q} = \text{Ambient ionization rate}

\text{Time (us)}

\text{D-dot (A/m²)}

\text{B-dot (T/µs)}
TRIGGERED LIGHTNING NONLINEAR MODEL PARAMETRIC STUDY

\[ E = 1.9 \times 10^5 \]
\[ Q = 0 \]

D-dot (A/square meter)

B-dot (T/S)

Time, \( \mu \) sec

TRIGGERED LIGHTNING NONLINEAR MODEL PARAMETRIC STUDY

\[ E = 1.5 \times 10^5 \]
\[ Q = -Q_m / 2 \]

D-dot (A/square meter)

B-dot (T/S)

Time, \( \mu \) sec

9-16
TRIGGERED LIGHTNING NONLINEAR MODEL
PARAMETRIC STUDY

\[ E = 2 \times 10^5 \quad Q = Q_m/2 \]

\[ \text{D-dot (A/square meter)} \]

\[ \text{B-dot (T/S)} \]

CONSERVATION OF ENERGY
IN NONLINEAR MODEL

Conservation of momentum: electrons, ions

\[ \frac{d}{dt} \left( n_e \varepsilon - n_i \varepsilon \right) \frac{\partial}{\partial \epsilon} \left( E \cdot \frac{1}{2} \epsilon + \dot{\delta} \right) - \frac{1}{\epsilon_0} \frac{\partial}{\partial \epsilon} \left( n_e \varepsilon - n_i \varepsilon \right) \]

Conservation of Energy: electrons

\[ \frac{d}{dt} \left( \frac{1}{2} n_e \varepsilon + n_i \varepsilon \right) - \frac{d}{dt} \left( Q_e \right) - \frac{d}{dt} \left( Q_i \right) - \frac{1}{2} \frac{d}{dt} \left( n_e \varepsilon \right) - \frac{1}{2} \frac{d}{dt} \left( n_i \varepsilon \right) \]

Conservation of Energy: ions

\[ \frac{d}{dt} \left( \frac{1}{2} n_e \varepsilon + n_i \varepsilon \right) - \frac{d}{dt} \left( Q_e \right) - \frac{d}{dt} \left( Q_i \right) - \frac{1}{2} \frac{d}{dt} \left( n_e \varepsilon \right) - \frac{1}{2} \frac{d}{dt} \left( n_i \varepsilon \right) \]
ENERGY CONSERVATION PARAMETERS

- \( v_s \) - species velocity
- \( m_s \) - mass of electron or ion
- \( c \) - velocity of light
- \( p \) - partial pressure
- \( v_c \) - species collision frequency
- \( \varepsilon \) - species energy density; \( H \) - heavy particle; \( e \) - electron
- \( \varepsilon^* \) - ambient species energy density
- \( \varepsilon_d \) - energy density due to ambient ionization
- \( \varepsilon_{\text{ion}} \) - energy to ionize neutral particle
- \( \varepsilon_e \) - energy density diffusion
- \( \varepsilon_{\text{excitation}} \) - energy density transfer between species due to vibrational modes

LINEAR DATA INTERPRETATION METHODOLOGY - Current Injection Approach

For: \( i_L = \delta(t) \)

Compute: \( \delta_C(t) \)

Develop Transfer Function Relating Sensor Response to Source Current

\[ G(s) = \frac{\varepsilon[\delta_C(t)]}{\varepsilon[\delta(t)]} \]

Then use \( G(s) \) along with \( \varepsilon[\delta_F(t)] \) to compute Lightning Source Current

\[ I_L(s) = \varepsilon[\delta_F(t)] \]
LINEAR MODEL RESULTS VERSUS FLIGHT DATA

Responses from Linear Triggered Lightning Model (Solid Lines). D-Dot Forced to Match Measured Data Using Transfer Function Method. Measured Data from Flight 82-037, Run 4 (Dashed Lines)

LINEAR MODEL INJECTED CURRENT

9-19
APPARATUS FOR AIRCRAFT-LIGHTNING MODELING

.141 in. semigrid cable

1/2 in. helix cable

36 in. F-106 model

B-DOT \, D-DOT sensors

Oscilloscope with camera

Pulser

Vertical plugin Integrator

Sampling plugin

Ground plane

SCALE MODEL VERSUS FLIGHT RESONANCES

TEXAS TECH GRANT MAG 1-28

O USE OF HIGH RESISTIVITY WIRES IN LAB MODEL IMPROVED AGREEMENT OF RESONANCE DAMPING COMPARED TO FLIGHT DATA

<table>
<thead>
<tr>
<th>POLE NUMBER</th>
<th>MODEL</th>
<th>AIRCRAFT</th>
<th>MODEL</th>
<th>AIRCRAFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRST</td>
<td>-0.27</td>
<td>-0.18</td>
<td>7.51 MHz</td>
<td>6.50 MHz</td>
</tr>
<tr>
<td>SECOND</td>
<td>-0.24</td>
<td>-0.20</td>
<td>14.80 MHz</td>
<td>13.44 MHz</td>
</tr>
<tr>
<td>THIRD</td>
<td>-0.18</td>
<td>-0.25</td>
<td>18.56 MHz</td>
<td>20.55 MHz</td>
</tr>
<tr>
<td>FOURTH</td>
<td>-0.23</td>
<td>-0.25</td>
<td>24.15 MHz</td>
<td>28.05 MHz</td>
</tr>
<tr>
<td>FIFTH</td>
<td>-0.35</td>
<td>--</td>
<td>30.72 MHz</td>
<td>--</td>
</tr>
<tr>
<td>SIXTH</td>
<td>-0.20</td>
<td>-0.19</td>
<td>36.22 MHz</td>
<td>36.40 MHz</td>
</tr>
<tr>
<td>SEVENTH</td>
<td>-0.16</td>
<td>-0.14</td>
<td>40.01 MHz</td>
<td>41.40 MHz</td>
</tr>
</tbody>
</table>

9-20
RESONANCES VERSUS ATTACHMENT POINTS

Magnitude, $T/v$

Frequency, mHz

9-21
FIELD MILL ATTRIBUTES

- Two independent detection circuits

Synchronous demodulation: 400 samples/sec

- W. P. Winn, New Mexico Tech

Clamped detection: DC to 100kHz

- L. G. Smith, AF Cambridge Research Lab, 1963

Restores DC level lost by charge amp

- Complementary stator pairs achieve constant area

- Wide rotor-to-stator spacing lessens rain shorting
CLAMPED DETECTION
(L. G. SMITH, AFCRL, 1953)

5kHz AC DATA
200Hz MODULATION

A
STATORS
B
STATORS
A
CLAMP
B
CLAMP

A
(VOLTS)
B
(VOLTS)
SUM
(VOLTS)

TIME
TIME
COORDINATION SUMMARY

- AFWAL/FDL, Wright-Patterson AFB, Ohio
  - Atmospheric Electricity Hazards Protection for aircraft (AEHP) program
  - Convair 580 direct strike initiative
- FAA Technical Center, Atlantic City, New Jersey
  - Interagency Agreement FA77WA1-756
  - Convair 580
- AFWL, Kirtland AFB, New Mexico
  - F-106 simulated NEMP tests
  - Compare lightning/NEMP
COORDINATION SUMMARY

- National Interagency Coordination Group on Lightning and Static Electricity (NICG)
  - USAF, USA, USN, NOAA, FAA, NASA
  - International Lightning Conference
- Society of Automotive Engineers SAE AE-4L
  - Test standards and techniques

SUMMARY AND PLANS

- High altitude essentially complete
  Specific experiments for model verification
- Complete direct strike data base
  - Obtain direct lightning strike data representative of currents with large magnitudes and fast rates of rise expected of low-altitude discharges and return strokes based on existing ground-based measurements
  - 50 to 100 strikes correlated with simultaneous ground-based measurements
  - Approximately 3 years
- Complete development of data interpretation/analysis methodology
  - Capable of modeling lightning interaction with generic composite aircraft
  - Laboratory investigation of spark initiation

9-25
UPDATE OF LIGHTNING SIMULATION FACILITIES SURVEY, JANUARY 29, 1985
(LAWRENCE C. WALKO, AIR FORCE WRIGHT AERONAUTICAL LABORATORIES)
The use of sophisticated avionics systems and non-metallic structures has enhanced aircraft susceptibility to, and the need for protection from, the lightning threat. Some lightning aspects may be simulated and this has established lightning simulation as a valuable aid in aircraft design. The following is an overview of lightning simulation facilities in the United States and Europe.
### Table 1 - U.S. Government Lightning Test Facilities

<table>
<thead>
<tr>
<th>Facility</th>
<th>Type of Simulator</th>
<th>Peak Current or Voltage</th>
<th>Total Energy</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Air Force Wright Aeronautical Labs</td>
<td>High Voltage</td>
<td>300 kV</td>
<td>250 joules</td>
<td>general use</td>
</tr>
<tr>
<td></td>
<td>Mars</td>
<td>1.5 MV</td>
<td>26.3 kJ</td>
<td>arc attachment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.0 MV</td>
<td>91.2 kJ</td>
<td>arc attachment</td>
</tr>
<tr>
<td></td>
<td>High Current</td>
<td>1 kA</td>
<td>2 kJ</td>
<td>induced effects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 kA</td>
<td>24 kJ</td>
<td>induced effects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30 kA</td>
<td>36 kJ</td>
<td>induced effects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250 kA</td>
<td>300 kJ</td>
<td>high energy, structural damage</td>
</tr>
<tr>
<td>U.S. Navy</td>
<td>High Voltage</td>
<td>2 MV</td>
<td>33 kJ</td>
<td>arc attachment</td>
</tr>
<tr>
<td>Naval Air Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Center Potomac River, MD</td>
<td>High Current</td>
<td>120 kA</td>
<td>50 kJ</td>
<td>high energy, structural damage</td>
</tr>
<tr>
<td>Sandia National Laboratory</td>
<td>High Current</td>
<td>200 kA</td>
<td>224 kJ</td>
<td>full threat induced effects</td>
</tr>
</tbody>
</table>

### Table 2 - Airframe Manufacturers Lightning Test Facilities

<table>
<thead>
<tr>
<th>Facility</th>
<th>Type of Simulator</th>
<th>Peak Current or Voltage</th>
<th>Total Energy</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boeing Aircraft Company</td>
<td>High Current</td>
<td>20 kA</td>
<td>6.4 kJ</td>
<td>indirect effects</td>
</tr>
<tr>
<td>Seattle, WA</td>
<td></td>
<td>200 kA</td>
<td>680 kJ</td>
<td>indirect effects testing for AER AEP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 to 300 coulombs</td>
</tr>
<tr>
<td></td>
<td>High Coulomb</td>
<td>3 kA</td>
<td>1 kJ</td>
<td>current vs. time relationships</td>
</tr>
<tr>
<td></td>
<td>Transfer</td>
<td>10 msc to 1.0 sec</td>
<td></td>
<td>transient analysis transfer function</td>
</tr>
<tr>
<td></td>
<td>High Energy</td>
<td>square and ramp wave</td>
<td></td>
<td></td>
</tr>
<tr>
<td>McDonnell-Douglas</td>
<td>High Voltage</td>
<td>4 MV</td>
<td>40 kJ</td>
<td>full scale component large model tests</td>
</tr>
<tr>
<td>St. Louis, MO</td>
<td></td>
<td>1.65 MV</td>
<td>4 kJ</td>
<td>induced voltage test</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.3 MV</td>
<td>2.4 kJ</td>
<td>remote induced tests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>800 kV</td>
<td>24 kJ</td>
<td>arc attachment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>400 kV</td>
<td>1 kJ</td>
<td>general lab use</td>
</tr>
<tr>
<td></td>
<td>High Current</td>
<td>30 kA</td>
<td>240 kJ</td>
<td>indirect effects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300 kA</td>
<td>660 kJ</td>
<td>high current damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150 kA</td>
<td>192 kJ</td>
<td>high current restrike</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 kA</td>
<td>480 kJ</td>
<td>intermediate and continuing current</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 kA</td>
<td>240 kJ</td>
<td>continuing current restrike tests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50 kA</td>
<td>6 kJ</td>
<td></td>
</tr>
<tr>
<td>Lockheed-Georgia</td>
<td>High Voltage</td>
<td>500 kV</td>
<td>7.2 kJ</td>
<td>arc attachment</td>
</tr>
<tr>
<td></td>
<td>High Current</td>
<td>200 kA</td>
<td>100 kJ</td>
<td>direct effects</td>
</tr>
<tr>
<td></td>
<td>High Coulomb</td>
<td>200 A</td>
<td></td>
<td>3 to 5 sec duration</td>
</tr>
<tr>
<td>Northrop Corp</td>
<td>High Voltage</td>
<td>1.2 MV</td>
<td></td>
<td>attachment studies</td>
</tr>
</tbody>
</table>

10-3
### Table 3 - Independent Laboratory Lightning Test Facilities

<table>
<thead>
<tr>
<th>Facility</th>
<th>Type of Simulator</th>
<th>Peak Current or Voltage</th>
<th>Total Energy</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightning Technologies Inc.</td>
<td>High Voltage</td>
<td>0.5 MV</td>
<td>6 kJ</td>
<td>attachment studies</td>
</tr>
<tr>
<td></td>
<td>Higher voltage generator under construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High Current</td>
<td>200 kA</td>
<td>50 kJ</td>
<td>high current damage</td>
</tr>
<tr>
<td>Lightning &amp; Transients</td>
<td>High Voltage</td>
<td>2.4 MV</td>
<td>29 kJ</td>
<td>arc attachment</td>
</tr>
<tr>
<td>Research Inst.</td>
<td>&quot;</td>
<td>4 MV</td>
<td>64 kJ</td>
<td>arc attachment</td>
</tr>
<tr>
<td></td>
<td>High Current</td>
<td>270 kA</td>
<td>87.5 kJ</td>
<td>initial return stroke</td>
</tr>
<tr>
<td></td>
<td></td>
<td>180 kA</td>
<td>60 kJ</td>
<td>initial and subsequent strokes</td>
</tr>
<tr>
<td>Intermediate Current</td>
<td>6.6 kA</td>
<td></td>
<td>65 kJ</td>
<td>physical damage</td>
</tr>
<tr>
<td>Continuing Current</td>
<td>1 kA</td>
<td></td>
<td></td>
<td>physical damage</td>
</tr>
</tbody>
</table>

### Table 4 - European Laboratory Lightning Test Facilities

<table>
<thead>
<tr>
<th>Facility</th>
<th>Type of Simulator</th>
<th>Peak Current or Voltage</th>
<th>Total Energy</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culham Laboratory Abingdon</td>
<td>High Current</td>
<td>200 kA</td>
<td>140 kJ</td>
<td>initial stroke</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>&quot;</td>
<td>50 - 100 kA</td>
<td>600 kJ</td>
<td>intermediate and continuing currents</td>
</tr>
<tr>
<td></td>
<td>&quot;</td>
<td>100 kA</td>
<td>40 kJ</td>
<td>fast rise subsequent return strokes, induced measurements</td>
</tr>
<tr>
<td>Centre D'Essais Aeronautique De Toulouse (C.E.A.T)</td>
<td>High Voltage</td>
<td>5 MV</td>
<td>62.5 kJ</td>
<td>arc attachment</td>
</tr>
<tr>
<td></td>
<td>High Current</td>
<td>200 kA</td>
<td>100 kJ</td>
<td>induced effects, composite materials testing</td>
</tr>
</tbody>
</table>
Lightning Simulation Facilities

McDonnell Douglas Aircraft Company
Long Beach, California

High Voltage Power Supplies
60 kV, 75 kV, 100 kV, 150 kV

Lightning Generators

- High Voltage Impulse 1,600 kV, 160 Kilojoules, 1,350 kV/μ sec 60 kA
- Very High Rate-of-Rise 50 kV, 11 Kilojoules, 100 kA/μ sec 110 kA
- High Rate-of-Rise 150 kV, 5.6 Kilojoules, 40 kA/μ sec 60 kA
- High Current 75 kV, 256 Kilojoules, 85 kA/μ sec 400 kA
- High Energy 390 V, 100 Kilojoules, 700 A, 500 Coulombs

P-Static Test Simulator

- Uniform Charge Spray Fixture, 4 by 8 ft, 150 kV

Simulation Test Fixtures

- Welded Solid Aluminum Coaxial Cylinder, 10 ft Diameter, 12 ft High
- Full Scale Mock-Up of Wing-Root/Fuselage
- Wire Cylinder, 50 ft in Diameter, 50 ft Long

Instrumentation

- Computerized Digital Waveform Processing System
- Digital and Analog Transient Recording Equipment
- Four-Channel Fiber-Optic Signal-Transmission System
- Solid Metal Shielded Enclosure, 8 by 11 ft
LIGHTNING TEST CAPABILITIES

Lightning Technologies, Inc.
10 Downing Parkway
Pittsfield, Massachusetts 01201

High Current

Component A - MIL-STD-1757
30 μF at 100 kV
150 kJ

We can inject a 180 kA, $1.6 \times 10^6 A^2$ s into a test circuit containing 75 milliohms and 5.4 μH. The test generator contains a nominal 1.5 μH and 12 milliohms of impedance, thus the test item can contain 63 milliohms and 4 μH of impedance. The test item inductance is configuration dependent and can be controlled to some extent.

Component B - MIL-STD-1757
520 F at 20 kV
100 kJ, 10 coulombs

The circuit contains 1.6 mH of inductance and 3.6 ohms of resistance which can be removed to accommodate a high impedance test item.

Component C - MIL-STD-1757

Eighty-one series 12 volt automotive batteries connected through 1.8 ohms and 3 mH. Various circuit resistors can be added to increase resistance from 1.8 and 3.2 ohms and the breaker can be timed to give durations of 0.1 to 1.4 seconds.

High Voltage

Waveform A - MIL-STD-1757

1500 kV at 16.7 nF is capable of providing a 1000 kV/μs breakdown for one meter. Test items requiring two meters or more, 1000 kV/μs tests are tested at the General Electric High Voltage Laboratory where two 5 MV and one 6.2 MV generators are available.

Miscellaneous

Circuits and experience available to perform various tests including but not limited to the following:

- Aircraft Lightning Induced Voltage Tests
- Electric Field Tests 500 kV/m pulse, 100 kV/m DC
- Magnetic Field Tests 0-5000 A/m single pulse
  (1MHZ Damped Sine) 0-100 A/m repetitive pulse
- Equipment (black box) Transient Design Verification Tests
UPDATE OF THE ICOLSE CONFERENCE IN PARIS, JUNE 1985
(MR. L. WALKO)
December 19, 1984

Mrs. Danielle Kerneur, Manager
SCTTV Transatour Passages
34, rue R. Giraudineau 94300 Vincennes
Paris, France

Reference: "ICOLSE"—International Conference on Lightning and Static Electricity.

Good Morning Mrs. Kerneur:

Before getting down to the business at hand, Kaye and I thank you and Peter for the wonderful hospitality you both extended to us on our recent visit to your beautiful city. We thoroughly enjoyed the social activities with you, Paul and Peter. It was rather like being at home, away from home.

Peter offered me many special "Introductions", several of which I am returning herewith as we simply did not have the time to enjoy all these activities. Perhaps you have other uses for them. Tell Peter the show at the Latin Paradise was simply GRAND. He should not hesitate to recommend the show to anyone. It didn't even matter what language the guests spoke, all can fully understand the entire program.

Now, down to business.

* By copies of this letter, I am strongly recommending to Jean-Michel Contant and Joseph Taillet that they consider that the Awards Banquet be held on the river cruise we took together. The size of the boat is right, the food is outstanding and the atmosphere is perfect for any visitor to the conference. Further, they will have a captive audience, for the right amount of time. And if the price of the dinner cruise is in the conference fee, all will attend.

* The Hotel arrangements seem to be at the right price. This will let us offer a choice of costs to the traveler. While the Montparnasse Park Hotel was 1st Class, we were not impressed with the efficiency of their operations, considering the cost. I should add that I have plenty of Hotel Mercure brochures, but only one for the Eiffel Kennedy. I need about 250 of each of the hotels that are to be recommended. Will you send them to me?

* Transfers from the airport to the hotel on arrival will be most difficult to arrange. I think it best to recommend that the traveler take the Air France bus to downtown, then a Taxi to their hotel. Returning to the airport from a hotel may be easier to plan. After the conference, departures can be identified, and arrangements can be made. We will "attack" this during the conference.

Page 1 of 2
Concerning the Ladies' Program (we refer to this as the SPOUSES' Program), we will detail the information you have provided in a brochure for a future mailing in North America. The responders will have to indicate the tours they will want, and pay for them in advance. This way we will have a count, and can plan the event.

The "Post Tours" will be handled the same way, in advance. However it may be that some visitors will decide to join the tour when they are already in Paris. I suppose this can be handled?

I agree that the Hotel Nikko is outrageously expensive, and from people we know that stayed there very recently, not worth it. There seems to be quite a few three star hotels around that you might look into. For instance, we stayed the last three days we were in Paris at the Terrass Hotel, just one block above the Hotel Mercure. It was clean, efficient, comfortable and I might add, inexpensive.

I believe I have covered all the points that we must "go" with. If you have any corrections, additions or deletions please let me know before February 1st, 1985.

Thank you again for your kind assistance. Our very best to Paul and Peter.

Sincerely,
Electromagnetic Engineering Inc.

Walter D. Kerchar, P.E.
President

cc: Jean-Michel Contant, AAAF
    Dr. Joseph Taillet, ICOLSE
    Jill, First Class Travel - Poulsbo, Wa.
    G.A.M. Odam, European Coordinator, NICG
    L.C. Walko, 1986 Chairman, LASE Conference
    Steering Committee, National Interagency Coordinating Group (NICG)
Dear Mr. Rissenden,

This is to confirm that we planned for the seventeen delegate.

Travel arrangements:

From Cape Town to Cape (air fare)
At Hendy's Manor Park Hotel overnight, we had to change our plane and we found a nice, cheap hotel.
Total Nightly Stay = 10 rooms
Price = single or double, including continental breakfast = 450 Fr.
From June 9th to June 13th (conference) =
Total Nightly Stay (as above)
Total Resort Entertainment
12 double rooms and 20 single rooms
Price = single 445 Fr.
double 475 Fr.
Conference breakfast 35 Fr. per person
one child under 12 in parents' room = free

Departure:
From GCT Airport to hotel or vice versa (minimum 25 persons)
For person = 65 Fr.
Conference programme (minimum 25 persons)
Monday June 9th
8.30am = 13km = Breakfast Paris
10.00am = 5km = Return Paris
For person = 75 Fr.
Tuesday June 10th
9am = 7km = Versailles and castle meeting
Incl. lunch
For person = 100 Fr.
Wednesday June 11th
9.30am = 13km = Bus trip on the Banks including bus transfer
For person = 75 Fr.
after noon = Pleasure ride
Festive lunch
- Banks and Champagne, one day
- Menu not included
- Price per person = 350 Fr.
- Loire Valley, two days
- Incl. meals and accommodation
- Price per person = 540 Fr.
- Versailles and castle, two days
- Incl. meals and accommodation
- Price per person = 1,500 Fr.

If you have an optional booking in Hotel Rhine (four stars) for
20 rooms from June 9th to 13th
Price = single 1,600 Fr.
Price = double 1,700 Fr.
Incl. continental breakfast
The only argument and no suggest to cancel this optional booking.
What do you think about it?

Many thanks

Danielle Sanguinetti (Mrs)
Manager
FAA TECHNICAL CENTER R&D OVERVIEW AND
PLANNED FUTURE ACTIVITIES (MR. MIKE GLYNN)
FAA TECHNICAL CENTER

R&D

OVERVIEW & PLANNED

FUTURE ACTIVITIES

• DIRECT STRIKE LIGHTNING

84

C-130/F-106/CV-580
FLORIDA '84'
ANALYSIS

FUTURE

TAIL BOOM

ADDITION INSTRUMENTATION

FLORIDA '85'

LANGLEY/WALLOPS

LEMP

NEMP

BEYOND 86

FLIGHTS

DECOMMISSION

12-2
- HIGH ALTITUDE DIRECT STRIKE
  PAST
  FUTURE
  NASA BRIEFING

- GEOGRAPHIC STUDIES
  INTENT
  MANPOWER & DOLLARS
  WORLDWIDE

- HISTORICAL STUDY
  LTI
  CONSOLIDATED DATA BASE
  EXPANDED AREA
  DATA

- INDIRECT EFFECTS (ADP)
  USAF - BRIEFING
  FAA SUPPORTS
  ACAP

- DIRECT STRIKE HAZARDS DEFINITION
  SHORT MANPOWER & DOLLARS
  COMBINES
  F-106
  CV-580
  GEOGRAPHIC
  HISTORICAL
  COMPLIMENTS ADP/INDIRECT

- SEA (DR. COOLEY)
  LIGHTNING SIMULATION TECHNOLOGY
  COMPOSITE - ELECTRICAL PROPERTIES ANALYSIS
  BALLANCA MODEL

12-3
NASA Ames (Bill Larsen)

Bus Integrity
Latent Fault Measurement Methodology
Software Systems Errors
Detection and Correction
Software Reliability Assessment
Software Monitoring Redundancy
Aircraft Generated EMI

Digital System Validation Handbook

Volume I
Update
Sohar

Static Discharge

LTRI

Conclusion

Limited Resources
Composites
Deicing Systems - Antennas
NAVY ISSUES ON LIGHTNING RESEARCH* (DR. L. RUKNKE)

*Presentation not submitted for inclusion into minutes
PROTECTION OF U. S. ARMY AIRCRAFT FROM NATURAL ELECTRICAL HAZARDS - FUTURE NEEDS AND ACTIVITIES - (MR. DAVID ALBRIGHT DIRECTORATE FOR ENGINEERING US ARMY AVIATION SYSTEMS COMMAND ST. LOUIS, MO)
PROTECTION OF U.S. ARMY AIRCRAFT
FROM
NATURAL ELECTRICAL HAZARDS

- Future Needs and Activities -

DAVID L. ALBRIGHT
Directorate for Engineering
US Army Aviation Systems Command
St. Louis, MO 63120-1798
28-29 January 1985
1. Recapitulation.

Yesterday I spoke about the past year's activities at AVSCOM, and in those discussions touched on several problems with regard to specifying design and test requirements for protection against lightning and static electricity hazards that continue to be troublesome. I'll restate them more explicitly today, discuss some solutions, and finish up my presentation by giving you a brief status report on the Advanced Composite Aircraft Program (ACAP).

2. Specifying Lightning Protection.

   a. Need for a Requirements Document.

      (1) Problem. We lack an adequate lightning protection requirements document with the result that we currently have to generate many words in lieu of one concise reference to a military standard. The problem with the current approach is the potential lack of consistency among programs as well as the danger of under-/over-specifying the requirement.

      (2) Solution. The current solution is the ongoing development of a lightning protection requirements military standard being developed by SAE Committee AE4L for the Air Force, and for eventual acceptance by all of the other services. It is hoped that this standard can be used in the Army's upcoming LHX program.

   b. Protection for Aircraft Modifications.

      (1) Problem. How to specify lightning protection design and qualification test requirements for a modification to an existing aircraft design when the basic aircraft itself has not been specifically lightning hardened.

      (2) Solution. One current solution pertains to the weaponization of helicopters and simply states that a direct lightning strike to the aircraft shall not arm, detonate, launch, or jettison the weapon for both the parked and airborne conditions. Most lightning strikes to Army helicopters have been on the ground. Variations involve precluding inerting of the weapon as well, or protection from nearby strikes versus direct strikes. The weapons themselves generally get lightning tested during their basic development, but sometimes only to nearby strikes and not direct strikes, e.g., a weapon initially designed for ground use only.

   c. Lightning Protection Demonstrations.

      (1) It is one thing to sell the notion of including lightning protection in the design requirements document for a program, and quite another to have hardware set aside for actual tests. Program Managers generally object to subjecting one of their scarce prototypes or initial production articles to lightning tests due to cost and schedule limitations.
Solution. The general pass-fail criterion for lightning protection is that there be no loss of aircraft or injury to crew. Accordingly, all new rotor blade and external fuel tank designs are lightning tested; since the material failure of one of these subsystems would generally be catastrophic. The UH-60A utility helicopter program did have a low-level induced effects test funded whereby the entire aircraft was tested; and the results, while being revealing, became expensive in the aftermath due to required maintenance actions. To date, no such test has been scheduled for other major aircraft systems. At best, what has been required is a lightning protection survey which involves some analyses, model testing, and an itemization of potential hazards with proposed fixes. If any service is really serious about producing an aircraft with an all-weather capability, lightning testing of full-scale aircraft is required; and the pass-fail criterion must be more than just being able to make a safe emergency landing.

d. Lightning Induced Transients.

(1) Problem. If one were to levy a lightning protection specification against induced effects for an entire aircraft, one need not get quantitative; since it would be up to the prime contractor to make trade-offs between shielding in the airframe and hardening in the subsystem. This becomes a problem, however, when government furnished equipment (GFE) is involved; whereby the GFE is developed independent of the aircraft. This could even be a problem for the prime contractor, since he needs to make early decisions regarding the above trade-offs.

(2) Solution. What is needed is a MIL-STD-704 or MIL-STD-461 type document for induced effects. Some Army programs have used the 500-volt pass-fail criterion of MIL-B-5087; but, as all of you know, this doesn't ensure that interfacing hardware will not be damaged.

3. Specifying Static Electricity Protection. The big problem here is that there is not only no comprehensive design requirements document, there is also no test requirements document. What is needed is an improvement over the one-liners in MIL-E-6051; namely, an effort similar to that being carried out for lightning.

(a) Need for a Requirements Document.

(1) Problem. We need a checklist for the myriad of potential hazards associated with static buildup and discharge for both ground operations (e.g., personnel handling, rearming, and refueling) and airborne operations (e.g., sling-load operations and avionics performance). As with lightning protection, lack of a static electricity protection requirements document requires that many words have to be generated in lieu of a concise reference to a military standard; with the result that requirements may not be consistent among different programs or even complete.

(2) Solution. Develop a static electricity hazards protection requirements document. It should be noted that MIL-B-5087 (the bonding specification) is just as inadequate for static electricity hazards as it is for lightning hazards.

(1) Problem. There are several sources which cite the personnel handling threat as being 25,000 volts and that due to a hovering helicopter as being 300,000 volts; however, there are numerous other hazards and circumstances which are not addressed by the above. Not only are the above criteria inadequate, they are not readily available for citation.

(2) Solution. Develop a static electricity hazards protection test document. This document should address such effects as vehicle construction and operational scenario. Recent experience with an external fuel tank of non-metallic construction pointed to the need for inclusion of specialized component testing as well as general aircraft testing.

4. Advanced Composite Aircraft Program (ACAP).

a. A Brief Review.

(1) To provide a technology base for engineering development of advanced composite airframes; e.g., LHX, JVX, and replacement of metal structures on current Army aircraft.

(2) Currently in competition: Sikorsky Aircraft and Bell Helicopter Textron (BHT).

(3) Each contractor built one static test article (STA), one tool proof article (TPA), and one flight test article.

(4) All nonconductive exposed composite surfaces have aluminum wire mesh. Composite joints are also metalized; except that Sikorsky uses foil and BHT uses wire mesh.

(5) The STA's and TPA's have the same degree of metalization as the flight test article, except that Sikorsky's TPA has no metalization.


(1) Negotiations are currently underway between Applied Technology Laboratory (Ft Eustis) and the Air Force to test both designs as a part of the Atmospheric Electrical Hazards Protection Advanced Development Program. Use of the TPA's would be desirable; however, the BHT TPA would not be available until sometime in 1986. Since the Sikorsky TPA has no metalization, the Sikorsky STA is being considered; which wouldn't be available until it has met other commitments in the coming years.

(2) Lightning electromagnetic pulse (LEMP) testing is planned for both STA's; Sikorsky's will be tested later this summer and BHT's will be tested the middle of next year. The flight test articles might be more desirable, but they have prior test commitments.
(3) Direct strike lightning testing is possible in the outyears, which would probably be performed on the STA's after LEMP testing. The order of consideration would be high voltage (low current) attachment tests, high current - average strike (20,000 amperes) tests, and lastly high current - severe strike (200,000 ampere) tests.

5. Concluding Remarks.

Most of you here present are engaged in various types of research on lightning and static electrification. We here at AVSCOM are more involved with using the results of your research. Accordingly, I thought it would be of value to you for me to relate some of the experiences, frustrations, lessons learned, and needs which have become evident in the day-to-day applications of the results of such research.
DIRECT STRIKE LIGHTNING OVERVIEW (MR. MIKE GLYNN, FAA TECHNICAL CENTER, ATLANTIC CITY AIRPORT, NJ)
MICHAEL S. GLYNN

FAA TECHNICAL CENTER
AIRCRAFT AND AIRPORT SYSTEMS
TECHNOLOGY DIVISION
FLIGHT SAFETY RESEARCH BRANCH

(609) 484-4138
LOW ALTITUDE
DIRECT STRIKE
LIGHTNING CHARACTERICATION
PROGRAM

BEFORE
YOU CAN SOLVE
A PROBLEM,
YOU MUST FIRST
UNDERSTAND IT.
PURPOSE

TO OBTAIN A DATA BASE OF LIGHTNING DIRECT STRIKES TO AIRCRAFT WHICH CAN BE ANALYZED FOR USE IN DEVELOPING CRITERIA FOR AIRCRAFT PROTECTION

APPROACH

CONDUCT A TWO-YEAR TEST PROGRAM IN AN INSTRUMENTED CV-580 AIRCRAFT TO OBTAIN LIGHTNING MEASUREMENTS

DIRECT-STRIKE
FLORIDA JULY-AUGUST 84 - 85

NEMP KIRKLAND AFB FALL 85

LEMP WRIGHT-PATTERSON AFB 84 - 85
- F-106 PROGRAM
  - HIGH ALTITUDE
  - NASA-LANGLEY
  - STrikes
    CLOUD-TO-CLOUD
    INTRA-CLOUD
- C-580 PROGRAM
  - LOW ALTITUDE (UP TO 20K)
  - FLORIDA AND NEW MEXICO
  - STrikes
    CLOUD-TO-GROUND
- ROCKET TRIGGERING PROGRAM
  - LOW ALTITUDE
  - FLORIDA
  - STrikes
    CLOUD-TO-GROUND

DATA BASE BENEFITS

- FAA
  CERTIFICATION
  REGULATORY
  ADVISORY
  VALIDATION
  PROCEDURES AND GUIDANCE

- INDUSTRY
  DESIGN
  MANUFACTURING
  VALIDATION
  MAINTENANCE
SENSOR LOCATIONS ON THE AIRCRAFT
SUMMARY - 1984 DIRECT STRIKE LIGHTNING DATA COLLECTED
(MAJ. P. RUSTAN, USAF, WRIGHT PATTERSON AFB, OH)
Table 1. ORGANIZATIONAL BLOCK DIAGRAM OF AGENCIES INVOLVED IN THE PROGRAM.
Figure 5. SURFACE CURRENT INSTRUMENTATION BLOCK DIAGRAM

Figure 7. DISPLACEMENT CURRENT INSTRUMENTATION BLOCK DIAGRAM FOR JNRW, JNLW, and JNWS
Figure 8. DISPLACEMENT CURRENT INSTRUMENTATION BLOCK DIAGRAM FOR J_{HFF}

TABLE 2

AIRCRAFT EXTERIOR TRANSIENT MEASUREMENTS

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Type</th>
<th>Area/ Sensitivity</th>
<th>Measurement Range</th>
<th>Frequency Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>J_{EN}</td>
<td>Resistive</td>
<td>5mΩ</td>
<td>10A - 2kA</td>
<td>DC - 500kHz(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2kA - 25kA</td>
<td>400kHz - 2MHz(2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100A - 25kA</td>
<td>40kHz - 80kHz(3)</td>
</tr>
<tr>
<td>J_{SHW}</td>
<td>Multi-Gap</td>
<td>10^{-3}m^2</td>
<td>5x10^{-6} - 0.5x10^{-3}</td>
<td>400kHz - 2MHz(2)</td>
</tr>
<tr>
<td>J_{SBRM}</td>
<td>Loop</td>
<td></td>
<td>5x10^{-6} - 5x10^{-6}</td>
<td>40kHz - B0MHz(3)</td>
</tr>
<tr>
<td>J_{STUF}</td>
<td>Multi-Gap</td>
<td></td>
<td>265 mA/m - 839 A/m</td>
<td>400kHz - 2MHz(2)</td>
</tr>
<tr>
<td>J_{SOUR}</td>
<td>Loop</td>
<td></td>
<td>5x10^{-6} - 1x10^{-6}</td>
<td>40kHz - B0MHz(3)</td>
</tr>
<tr>
<td>J_{NLVT}</td>
<td>Flush Plate</td>
<td>10^{-2}m^2</td>
<td>3.54x10^{-9} - 8.85x10^{-6}</td>
<td>400kHz - 2MHz(2)</td>
</tr>
<tr>
<td>J_{WVT}</td>
<td>Dipole</td>
<td></td>
<td>1 - 40 A/m^2</td>
<td>40Hz - B0MHz(3)</td>
</tr>
<tr>
<td>J_{WVU}</td>
<td>Flush Plate</td>
<td>5 x 10^{-3}m^2</td>
<td>2.25kV/m - 2.25MV/m</td>
<td>0.5Hz - 500kHz(1)</td>
</tr>
<tr>
<td>J_{NWF}</td>
<td>Dipole</td>
<td></td>
<td>100V/m - 316 kV/m</td>
<td>400kHz - 2MHz(2)</td>
</tr>
<tr>
<td>J_{NWF}</td>
<td>Spherical Dipole</td>
<td></td>
<td>100V/m - 316 kV/m</td>
<td>40Hz - B0MHz(3)</td>
</tr>
<tr>
<td>VHF 63</td>
<td>YHF Blade</td>
<td></td>
<td>63MHz, 60Hz B.W.</td>
<td>DC - 500kHz(1)</td>
</tr>
<tr>
<td>VHF 120</td>
<td>YHF Antenna</td>
<td></td>
<td>1200Hz</td>
<td>400 - 2MHz(2)</td>
</tr>
</tbody>
</table>

(1) FN Record on Honeywell H101 Instrumentation Recorder
(2) Direct Record on Honeywell H101 Instrumentation Recorder
(3) Recorded on Tektronix 76120 Waveform Digitizer
CV-580 AIRCRAFT INSTRUMENTATION BLOCK DIAGRAM
**Figure 14. CV-580 Aircraft Rack Layout**

<table>
<thead>
<tr>
<th>TYPE</th>
<th>ANDREW CORD</th>
<th>RG8/U</th>
<th>RG58C/U</th>
<th>RG174/U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutoff Freq., GHz</td>
<td>12</td>
<td>23</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Impedance, Ohms</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Velocity, X e</td>
<td>66</td>
<td>66</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>Attenu. dB/1000ft @100MHz</td>
<td>1.72</td>
<td>2.0</td>
<td>3.3</td>
<td>8.8</td>
</tr>
<tr>
<td>Nominal Size, Inch</td>
<td>0.25</td>
<td>0.405</td>
<td>0.195</td>
<td>0.10</td>
</tr>
<tr>
<td>Center Conductor</td>
<td>Copper</td>
<td>Copper</td>
<td>Copper</td>
<td>Copper</td>
</tr>
<tr>
<td>Solid,Corrugated</td>
<td>Copper</td>
<td>Copper</td>
<td>Copper</td>
<td>Copper</td>
</tr>
<tr>
<td>Outer Conductor</td>
<td>Copper</td>
<td>Braided</td>
<td>Braided</td>
<td>Braided</td>
</tr>
</tbody>
</table>

**Table 3. COAXIAL CABLE SPECIFICATIONS**

16-7
GROUND STATION INSTRUMENTATION BLOCK DIAGRAM

GROUND STATION MEASUREMENTS

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Type</th>
<th>Area</th>
<th>Measurement Range</th>
<th>Frequency Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>Flat Plate</td>
<td>0.05m²</td>
<td>500 V/m - 100 kV/m</td>
<td>0.1-500 kHz(1)</td>
</tr>
<tr>
<td>E2</td>
<td>Flat Plate</td>
<td>0.2 m²</td>
<td>50 V/m - 1 kV/m</td>
<td>0.1-500 kHz(1)</td>
</tr>
<tr>
<td>E3</td>
<td>Flat Plate</td>
<td>0.1 m²</td>
<td>2 x 10⁵ - 5 x 10⁹ V/m/s</td>
<td>50 Hz - 25 kHz(2)</td>
</tr>
<tr>
<td>E4</td>
<td>Flat Plate</td>
<td>0.2 m²</td>
<td>2 V/m - 2 kV/m</td>
<td>50 Hz - 2 kHz(3)</td>
</tr>
<tr>
<td>VHF</td>
<td>Flat Plate</td>
<td>0.06m²</td>
<td>63 kHz, 6 kHz B.W.</td>
<td>DC - 500 kHz(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DC - 25 kHz(2)</td>
</tr>
<tr>
<td>B1</td>
<td>Cylindrical</td>
<td>0.02m²</td>
<td>0.02 - 5 A/m</td>
<td>500 Hz - 2 kHz(3)</td>
</tr>
<tr>
<td></td>
<td>Helmholtz Loop</td>
<td></td>
<td>10⁵ - 2.5 x 10⁷ A/m/s</td>
<td>500 Hz - 25 kHz(2)</td>
</tr>
<tr>
<td>B2</td>
<td>Cylindrical</td>
<td>0.02m²</td>
<td>0.02 - 3 A/m</td>
<td>500 Hz - 2 kHz(3)</td>
</tr>
<tr>
<td></td>
<td>Helmholtz Loop</td>
<td></td>
<td>10⁵ - 2.5 x 10⁷ A/m/s</td>
<td>500 Hz - 25 kHz(2)</td>
</tr>
</tbody>
</table>

(1) FM Record on Honeywell HT01 Instrumentation Recorder
(2) Recorded on Tektronix 7612D Waveform Digitizer
(3) Direct Record on Honeywell HT01 Instrumentation Recorder

16-9
Displacement current density in kA/m² during the triggered pulse of the direct lightning attachment on 7 Aug. at 21:41:23 (left hand and vertical stabilizer) to noise level, expansion of 10.29 microseconds horizon.
T FUSELAGE 180,000 V/m
T RIGHT TIP 270 V/m
T LEFT TIP 106,000 V/m
T VERTICAL STABILIZER 48,000 V/m

Time Code 25 ns

Surface current density (Tesla/sec) during the triggered pulse in the direct lightning and attachment on the left as reported at 10.39 and 10.39 microseconds.

16-18
Overlays of the Surface Current Density at the Forward and Aft Fuselage Sensors Showing the Time Delay as the Current Propagated from the Attachment Point at the Nose Through the Fuselage and into the Wings. Flash on 17 Aug 84 at 21:36:01.

Overlays of the Surface Current Density at the Left and Right Wing Sensors Showing the Time Delay as the Current Propagated from the Attachment Point at the Nose Through the Fuselage and into the Wings. (Right Wing Trace Is Inverted.) Flash on 17 Aug 84 at 21:36:01.
DISPLACEMENT CURRENT DENSITY IN kA/cm² DURING THE TRIGGERED PULSE OF THE DIRECT LIGHTNING IMPACT ON 31 JULY 1968.  IN AT 23:50:01.  EXPANSION OF 10.24 MICROSECONDS PER VERTICAL INCH.
SURFACE CURRENT DENSITY (TESLA/SEC) DURING THE TRIGGERED PULSE OF THE DIRECT LIGHTNING ATTACHMENT ON 20 AUG. 20 AT 15:32:41. EXPANSION OF 10.24 MICROSECOND WINDOW.
SURFACE CURRENT DENSITY (TESLAS/SEC) DURING THE TERMINAL PHASE OF THE SUBJECT LIGHTNING ATTACHMENT ON 5 SEP. 84 AT 23:02:48. EXPONENTIAL GROWTH OF 16.24 YACC/SECOND VOLUME.

16-23
Overlays of the Displacement Current Density at the Right and Left Wingtip Sensors Showing the Time Delay as the Current Propagated from the Right Wingtip Attachment Point to the Left Wing and Fuselage. Flash on 5 Sep 84 at 21:53:05.
Overlays of the Displacement Current Density at the Right Wingtip and Vertical Stabilizer Sensors Showing the Time Delay as the Current Propagated from the Right Wingtip Attachment Point to the Left Wing and Fuselage. Flash on 5 Sep 84 at 21:53:05.

Overlays of the Surface Current Density at the Left and Right Wing Sensors Showing the Time Delay as the Current Propagated from the Right Wingtip Attachment Point to the Left Wing and Fuselage. Flash on 5 Sep 84 at 21:53:05.
Overlays of the Surface Current Density at the Forward and Aft Fuselage Sensors Showing the Time Delay as the Current Propagated from the Right Wingtip Attachment Point to the Left Wing and Fuselage. (Forward Fuselage Trace Is Inverted.)

Flash on 3 Sep '64 at 11:53:05.

16-26
<table>
<thead>
<tr>
<th>Flash No</th>
<th>Height (ft)</th>
<th>Triggered Discharge</th>
<th>Aircraft Charged</th>
<th>Leader Duration (sec)</th>
<th>Distance to Charged Region (m)</th>
<th>Streamers Propagated from Aircraft</th>
<th>Flash No</th>
<th>Digital System Threshold Level (V)</th>
<th>Digital System Triggred</th>
<th>DIGITIZER DATA</th>
<th>ANALOG DATA</th>
<th>Duration of Flash (ms)</th>
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<tbody>
<tr>
<td>1</td>
<td>14,000</td>
<td>Yes</td>
<td>Yes</td>
<td>2.1</td>
<td>315</td>
<td>Yes</td>
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<td>1500</td>
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<td>165</td>
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<td>14,000</td>
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<td>Yes</td>
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<td>6</td>
<td>4000</td>
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<td>135</td>
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<td>7</td>
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**INT* -** The discharge was not triggered by the presence of the aircraft but its path was affected by the aircraft.
Histogram showing the percentage of hours flown at different altitudes.

Histogram showing the percentage of lightning strikes at different altitudes.
SUMMARY OF 1984 FIELD MILL DATA
(MR. R. ANDERSON, NRL)
\[ \varepsilon_p = P_x \varepsilon_x + P_y \varepsilon_y + P_z \varepsilon_z + P_\theta \theta \]
\[ \varepsilon_s = \Delta_x \varepsilon_x + \Delta_y \varepsilon_y + \Delta_z \varepsilon_z + \Delta_\theta \theta \]

**From symmetry**
\[ \varepsilon_s = -P_x \varepsilon_x - P_y \varepsilon_y + P_z \varepsilon_z + P_\theta \theta \]

**But:**
\[ P_x \ll P_y \]
\[ P_3 \ll P_\theta \]

So
\[ \varepsilon_p = P_y \varepsilon_y + P_\theta \theta \]
\[ \varepsilon_s = -P_y \varepsilon_y + P_\theta \theta \]

Then
\[ \varepsilon_p - \varepsilon_s = 2P_y \varepsilon_y \]
\[ \varepsilon_p + \varepsilon_s \approx 2P_\theta \theta \]
\[ \varepsilon_F = f_x \varepsilon_x + f_z \varepsilon_z + f_\theta \theta \]
\[ \varepsilon_T = t_x \varepsilon_x + t_z \varepsilon_z + t_\theta \theta \]

\((f_y = t_y = 0 \text{ from symmetry})\)

**Now:**
\[ \theta = \frac{\varepsilon_p + \varepsilon_s}{2P_\theta} \]

Add \((-f_\theta \theta)\) to \(\varepsilon_F\)
Add \((-t_\theta \theta)\) to \(\varepsilon_T\)

**SEPARATION OF \(\varepsilon_x\) AND \(\varepsilon_z\)**

1. **ORTHOGONALITY**
2. \[ \frac{\partial \varepsilon_z}{\partial \theta} = 0 \text{ in roll} \]
### Table 1. Electric field data for 20 direct lightning strikes in 1984.

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PORT, CG FLASH 08/17/84

Figure 1

STBD, CG FLASH 08/17/84

Figure 2

17-9
ROCKET TRIGGERED LIGHTNING PROGRAM
(MR. W. JAFFERIS, NASA, KSC)
KENNEDY SPACE CENTER
ROCKET TRIGGERED LIGHTNING PROGRAM (RTLIP)

INTRODUCTION

- AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
  - A/B LIGHTNING MEASURING PROGRAM
- KSC NEEDS
- RESEARCH INTEREST
- RTLIP 1984 RESULTS
- RTLIP 1985 STATUS
- RECOMMENDATIONS
AFWAL AIRBORNE LIGHTNING MEASURING PROGRAM

OBJECTIVE
- INTER-AGENCY PROGRAM TO CHARACTERIZE LIGHTNING DANGER TO AEROSPACE VEHICLES

PARTICIPANTS
- AIR FORCE, FAA, US NAVY, CHET, ONERA & CENG (FRANCE), U OF A, U OF F, 
- SUNYA

SCOPE
- A TWO YEAR EFFORT THAT WILL USE GROUND BASED INSTRUMENTED ROCKET TRIGGERED LIGHTNING SITE AND AN INSTRUMENTED AIRCRAFT

KSC/ESMC PARTICIPATION
- PROVIDE A TEMPORARY TEST SITE FOR LIGHTNING TRIGGERING, POWER, COMMUNICATION, AND ACCESS- ACCOMPLISH OPERATION WITHIN ENVIRONMENTAL AND SAFETY GUIDELINES
- WEATHER FORECASTING AND OBSERVATIONS AND DATA
- VECTOR CONTROL, TRACKING OF A/C OVER KSC AND FLORIDA

ANTICIPATED RESULTS
- DETERMINATION OF CURRENT AND FIELDS RECEIVED BY AN AEROSPACE VEHICLE STRUCK BY LIGHTNING AND COMPARING RESULTS WITH SIMULTANEOUS CURRENT AND FIELD LEVELS OBTAINED AT KSC USING ROCKET TRIGGERED LIGHTNING. RESULTS TO BE SHARED WITH ALL PARTICIPANTS
### Reduced STS Schedule & Operation Lost Time

- Provide Lightning Protection for Critical Work Areas
  - Rocket Triggered Lightning will verify various designs
- Improve Adverse Weather Warning Reliability (Lightning with 5 miles)
  - Expanded Neso network will improve short term forecast (30 min.)
  - (L.P.)*X (F.C.R.)*K = Cost Avoidance

### Renewed Awareness to Lightning Related Problems

Renewed awareness to lightning related problems occurred because of the near disaster of Apollo 12; damage to spacecraft & GSE; Lost time due to retest and unnecessary work stoppage during Apollo and Skylab programs and schedule sensitivity of ASTP. Thru a lesson learned technique, the following improvements were initiated by operations:

- Reviewed and verified CX39 Area Lightning Protection Sys (ALPS)
- Eliminated "Tower Clear" rednt during adverse weather (LV5M)
- Improved Lightning Measuring Sys (LIVIS, CVLIS, Optic-Otv)
- Improved STS ALPS; Cat wire, external cable routing (TSR)
  - Damage Susceptibility Analysis (KSC-JSC)
- Extension of ALPS to Schedule Sensitive Areas (SCAPE, Hyper-Farms, PRSD . . .)
FURTHER IMPROVEMENTS ARE REQUIRED BECAUSE OF THE ACCELERATED LAUNCH RATE AND NEW LANDING REQUIREMENTS FOR THE STS VEHICLES (TILE, ELECTRONICS)

- FURTHER EXTENSION OF ALPS FOR SAFETY
  - PERSONNEL (LIGHTNING VOLTAGES & CURRENTS)
  - SENSITIVE FLIGHT HV & GSE, ORDNANCE (ELECTRIC & MAGNETIC FIELDS)
  - SRB DISASSEMBLY & RECOVERY, CRYO LH & LO STORAGE, ESA-60A AND DELTA SPIN
- IMPROVED WEATHER FORECASTING
  - LONG-TERM 1-3 DAYS (SCHEDULING)
  - SHORT-TERM 30 MIN (WORK FLOW), 2 HOURS (LANDING & CRYO LOADING)

<table>
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<tr>
<th>KSC NEEDS</th>
<th>NAME: W. JAFFERIS</th>
<th>CODE: SO</th>
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- AREA LIGHTNING PROTECTION SYS (ALPS) DESIGN, TO:
  - REDUCE MAGNETIC & ELECTRIC INDUCED FIELD LEVELS TO PREVENT DAMAGE TO FLIGHT HV & GSE & REDUCE ORDNANCE HAZARD

- BENEFITS
  - ECONOMICAL SOURCE OF NATURAL LIGHTNING TO:
    - VERIFY DESIGN OF GRD & A/B LIGHTNING PROTECTION SYSTEM AND DEMONSTRATE EFFECTIVENESS
    - VERIFY LIGHTNING LOCATION SYSTEMS
    - FORECASTING OF THUNDERSTORMS

- REQUIRES
  - ELECTRIC & MAGNETIC FIELD MEASUREMENTS INSIDE & OUTSIDE PROTECTED AREA
  - TYPICAL ORDNANCE CIRCUITS WITH INITIATORS CONNECTED COULD BE PLACED INSIDE/OUTSIDE PROTECTED AREAS TO DEMONSTRATE EFFECTIVENESS
  - CORELATION OF OPERATIONAL LIGHTNING MEASUREMENTS WITH A/B GROUND DATA DURING NATURAL & TRIGGERED LIGHTNING EVENTS
- UNIVERSITY OF FLORIDA - KSC AND NSF FUNDED
  - HORIZONTAL AND VERTICAL ELECTRIC FIELDS
  - LIGHTNING CURRENT CHARACTERISTICS & GEOMETRIC SHAPE

- UNIVERSITY OF ARIZONA - KSC & NSF FUNDED
  - MAXWELL CURRENTS, ELECTRIC AND MAGNETIC FIELDS
  - THUNDERSTORM CHARACTERISTICS, LIGHTNING & CHARGE LOCATIONS
  - SUPPORT FOR NOAA-ERL WIND DIV. STUDY TO IMPROVE SHORT TERM FORECASTING

- STATE UNIVERSITY OF NEW YORK AT ALBANY (SUNYA) NSF FUNDED
  - LIGHTNING CURRENT CHARACTERISTIC - VELOCITY OF RETURN STROKE USING STREAK CAMERA TECHNIQUE
- Naval Research Laboratory - Navy
  - A/B Electric Field Mill
  - Electric and Magnetic Fields (UHF)

- Air Force Wright Aeronautical Laboratory & FAA - Self Funded
  - A/B Ground Electric & Magnetic Fields
  - Direct and Indirect Lightning Current Characteristics
  - Cloud to Ground and Intercloud Lightning
  - Thunderstorm Turbulence
  - Optical Recording

- ONERA, CENG and CMET
  - A/B and Ground Electric and Magnetic Fields
  - Lightning Current Characteristics
    - Natural and Triggered Lightning
### 1984 RTLP Results

**Shuttle Operations**

- **Airborne, FAA, Navy, and ONERA**
  - Duration: 11 June thru 19 September
  - 27 Missions flown
  - 21 Natural Lightning Events
  - 6 Near-by Triggered Lightning Events
  - Substantial A/B & Ground Data Collected - Analysis Underway
  - Slight A/C Damage with Some Down Time

- **Ground - RTLP**
  - Duration: 11 July thru 28 August
  - 4 Storm Days
  - 8 Triggered Events
    - 4 Triggers resulted in Natural-Like Return Strokes.
    - Peak Current: 43KA
  - Substantial Ground Base Data Collected - Analysis Underway

- **Clean Up**
  - Stowage of 23 Rockets and Launching Equipment
  - Preliminary Planning for RTLP 85 Started

### KSC Accomplishments

- **Safe Operations and Procedures**
  - No STS Interference

- **With ESMC Vector Controller**
  - Demonstrated ability to rocket triggered lightning on time. (Plane over target, rocket at altitude relative to electric field)

- **With ESMC/WE**
  - Provided timely weather forecast and observations
  - Collected unique set of wind, lightning & meteorological data for NOAA-ERL Wind Divergence Study and other interested researchers

- **Demonstrated Lightning Protection System Techniques**
  - Bonding, grounding and shielding - little effects if any to control/instrument van with lightning within 150 feet

- **Public Awareness of what is being done to protect STS elements**

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18-8
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<th>1984 RTLP RESULTS (CONTINUED)</th>
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**Graphs and Diagrams:**

- Three graphs or diagrams are shown, likely related to shuttle operations data.

18-9
MANPOWER:
- CENG - FRENCH LAUNCH CREW (2)/EQUIPMENT
- KSC/SM - (1) SUPPORT, (1) OPS, (1) PROJECT MANAGER
- CONTRACTOR - INSTRUMENTATION/COMM & PLANNING TIC

SUPPORT MANPOWER
- SITE PREPARATION (WILDLIFE REFUGE BUILDING #5 (F5-2151))
- POWER
- TIMING
- TELEPHONE
- MISCELLANEOUS

TIME PERIOD:
60 DAYS (JUNE, JULY, AUGUST)
1985 ROCKET TRIGGERED LIGHTNING PROGRAM
(CONTINUED)

Funds - French only: $100K
- Additional rockets (72) and French crew (2 or 3).
- Instrumentation and Comm
- KSC support $30k
  - TIC 15k
  - E66 10k
  - Simulator 5k
  - SPC ?

- Triggered Lightning Site
  Wildlife Refuge Building #5 (F5-2151)
1985 ROCKET TRIGGERED LIGHTNING PROGRAM
(Continued)

15 JANUARY 1985

WILDLIFE REFUGE BUILDING #5 (F5-2151)

RECOMMENDATION

- Approve the extended program and give go ahead to amend existing MOU for CD signature.
- Consider 1985 RTLP as one small step toward the foundation of a permanent KSC Atmospheric Research Facility.
- Support planning/funding for known research interest. Consider sponsoring Interagency Briefing of 17 August 1984 data RTLP - Short Term Forecasting.
NOTICE OF MEETING

SIXTH ANNUAL MEETING OF THE NICG OF THE NATIONAL
ATMOSPHERIC ELECTRICITY HAZARDS PROTECTION PROGRAM
SUBJECT: Sixth Meeting of the National Interagency Coordination Group of the National Atmospheric Electricity Hazard Protection Program

SEE DISTRIBUTION

1. The subject meeting is to be held in St. Louis, MO, on 28-29 Jan 85. The meeting will be held at the Ramada Inn (near the airport), 9636 Natural Bridge Road, and will commence at 1230 hours on 28 Jan.

2. In addition, a special briefing will be presented on Wednesday, 30 Jan, regarding results of the C-580 flight test program to date. A tentative agenda is provided in Encl 1. The undersigned, who is with the US Army Aviation Systems Command (AVSCOM), will preside as chairman for this session.

3. One of the primary purposes of this meeting is to discuss each agency's programs, projects, and concerns. Historically, these meetings have been very productive in the transfer of information which has resulted in multi-agency collective research efforts. With the continued restrain of resources (both manpower and money), it is imperative that the agencies continue to coalesce their research activities. This year's meeting format will be slightly different from that of previous years in that the first day will address each agency's past year's activities, followed by future plans and issues on the second day.

4. A block of rooms has been set aside for our committee at the above Ramada Inn; however, each committee member is expected to make his own motel arrangements. You are requested to make motel reservations through the AVSCOM Protocol Office, commercial 314-263-1046 or AUTOVON 693-1046. Additional information such as directions and arrangements for special audio/visual equipment should also be made with the Protocol Office.

5. If you need any additional information or encounter any difficulties in which we could be of help, please contact the undersigned at commercial 314-263-1695 or AUTOVON 693-1695. Incidentally, the phone number of the Ramada Inn is 314-426-4700.
AMSAV-ES
SUBJECT: Sixth Meeting of the National Interagency Coordination Group of the National Atmospheric Electricity Hazards Protection Program

6. For those NICG committee members who are also members of SAE subcommittee on lightning, the next AE4L meeting will be at McDonnell Douglas, also in St. Louis, MO, near the airport, on 31 Jan and 1 Feb 85. A separate letter of invitation with details will be forthcoming from that organization.

7. In an effort to expedite publication of the minutes, you are requested to supply a reproducible copy of your presentation to the secretariat at the completion of the session.

8. I am looking forward to your attendance at the meeting.

DAVID L. ALBRIGHT
Chairman

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Commander Max Bellune  
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The Pentagon  
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Air Force Wright Aeronautical Lab  
Wright-Patterson AFB, OH 45433

Mr. M. Glynn  
FAA Technical Center  
ACT-340  
Atlantic City Airport, NJ 08405

19-3
AMSAV-ES

SUBJECT: Sixth Meeting of the National Interagency Coordination Group of the National Atmospheric Electricity Hazards Protection Program

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ACT-340
Atlantic City Airport, NJ 08405

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National Severe Storms Lab
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Norman, OK 73069

Dr. Donald R. MacGorman
NOAA
National Severe Storms Lab
1313 Halley Circle
Norman, OK 73069

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AFWAL/FIEA
WPAFB
Dayton, OH 45433

Mr. John P. O'Neill
AFWL/NTCA
Kirtland AFB
Albuquerque, NM 87117

Mr. William Walker
NADC
Code 20P3
Warminster, PA 18974

Mr. Norm Crabill
Code 130
NASA-Langley Research Center
Hampton, VA 23665

Dr. J. Birken
NAVAIR
Comm Naval Air Sys Cmd
Washington, DC 20361

Director, USARTL (AVSCOM)
ATTN: SAVDL-ATL-ATA
Ft Eustis, VA 23604

Mr. David Holmes
Chief, Sounding Sys Branch, OA/W522
National Weather Service
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Silver Spring, MD 20910

Mr. Jack Lippert
AFWAL/FIEA
Air Force Wright Aeronautical Lab
Wright-Patterson AFB, OH 45433

Mr. Larry Walko
AFWAL/FIESL
WPAFB
Dayton, OH 45433

Major Pete Rustin
AFWAL/FIESL
WPAFB
Dayton, OH 45433

Mr. J. Corbin
ASD/ENACE
WPAFB
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Mr. Bruce Fisher
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NASA-Langley Research Center
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Mr. Felix Pitts
Code 130
NASA-Langley Research Center
Hampton, VA 23665

Mr. Jim Foster
Code 9482
Naval Air Engineering Center
Lakehurst, NJ 08733

Mr. D. Suiter
NASA
Johnson Space Center (Code MD-3)
Houston, TX 77058

Dr. L. Ruhnke
Naval Research Lab
Code 4110
Washington, DC 20375
NICG MEETING, 28-29 JANUARY 1985

TENTATIVE AGENDA

28 January 1985 (Monday)

1230 Hours Welcome

1245 Hours Review of Minutes from Previous Meeting (NOAA, Norman, OK, 27-28 Mar 84)

Replacement for Secretariat

1330 Hours Overview of National Severe Storm Laboratory (NSSL) Activity - A Progress Review (Dr. D. MacGorman, NSSL, NOAA, Norman, OK)

1400 Hours Air Force Wright Aeronautical Laboratory (AFWAL) Activity for the Past Year (Mr. L. Walko, Atmospheric Electricity Hazards Group, WPAFB, Dayton, OH)

1430 Hours Atmospheric Electrical Hazards Protection (AEHP) Advanced Development Program (ADP) Overview (Mr. R. Beavin, Flight Dynamics Laboratory, WPAFB, Dayton, OH)

1500 Hours Break

1515 Hours Lightning Protection Standard for Military Aircraft - An Overview (Dr. J. Corbin, Aeronautical System Division, WPAFB Dayton, OH)

1545 Hours US Army Program for Protection of Aircraft Against Natural EM Hazards - A Progress Review (Mr. D. Albright, AVSCOM, St. Louis, MO)

1615 Hours Design Guide for Lightning Protection of Advanced Fuel Systems - A Progress Review (Mr. W. Walker, Naval Air Development Center, Warminster, PA)

1645 Hours Navy Basic Research Program on Lightning - An Overview (Dr. L. Ruhnke, Naval Research Laboratory, Washington, DC)

1715 Hours FAA R&D Technical Center Accomplishments (Dr. T. Carro, FAA Technical Center, Atlantic City, NJ)

1745 Hours Naval Air Systems Command Activities - A Progress Review (Mr. J. Birken, NAVAIRSYSCOM, Washington, DC)

1815 Hours Adjourn
29 January 1985 (Tuesday)

0800 Hours  Summary of NASA LaRC Lightning Characterization and Effects (Mr. F. Pitts, NASA-Langley Research Center, Hampton, VA)

0830 Hours  Update of Lightning Simulation Facilities Survey (Mr. L. Walko)

0900 Hours  Update of the ICOLSE Conference in Paris, Jun 85 (Mr. L. Walko)

0915 Hours  All Composite Aircraft Program (ACAP) - A Lightning/Avionics/Electromagnetic Assessment (Mr. T. Mazza, AVSCOM Applied Technology Laboratory, Ft Eustis, VA)

0945 Hours  Break

1000 Hours  FAA R&D Technical Center Planned Future Activity (Dr. T. Carro)

1030 Hours  Navy Issues on Lightning Research (Dr. L. Ruhnke)

1100 Hours  NAVAIRS/SYSCOM Future Activities (Mr. J. Birken)

1130 Hours  US Army Programs for Protection of Aircraft Against Natural Electromagnetic Hazards - Future Activities and Needs (Mr. D. Albright)

1200 Hours  Lunch

1300 Hours  AFWAL Future Activities (Mr. L. Walko)

1330 Hours  AEHP ADP Demonstration Planning and Workshop Plan (Mr. R. Beavin)

1400 Hours  Future Concerns (Dr. J. Corbin)

1420 Hours  Spring Operations and Analysis (Dr. D. MacGorman)

1430 Hours  Break

1500 Hours  General Issues, Discussions, Closing Remarks

Publication of Minutes

Previous Action Items:

Mr. L. Walko - National lightning Test Facility

Dr. D. MacGorman - Review Questionnaires

Next NICG Meeting (FAA)

1600 Hours  Status Review of 1986 Conference, Dayton, OH (Mr. L. Walko)

1800 Hours  Adjourn
## ATTENDANCE (NICG)

**NICG Meeting**  
St. Louis, MO  
28-29 January 1985

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Phone</th>
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<tr>
<td>David L. Albright</td>
<td>U.S. Army-AVSCOM</td>
<td>AV 693-1695</td>
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<tr>
<td></td>
<td></td>
<td>(314) 263-1695</td>
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<tr>
<td>Lawrence C. Walko</td>
<td>U.S. Air Force AFSAL/FIESL</td>
<td>AV 787-7718</td>
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<td>(513) 257-7718</td>
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<tr>
<td>Nickolus O. Rasch</td>
<td>FAA/APM-700</td>
<td>(202) 426-1410</td>
</tr>
<tr>
<td>Felix L. Pitts</td>
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</table>
### ATTENDANCE (CV-580)

**CV-580 Direct Strike Lightning**<br>**Meeting - 30 January 1985**

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