TITLE/APPROVAL PAGE

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TS
This report contains a summary of the 1977 Thunderstorm Research International Program (TRIP 77) studies conducted at the NASA John F. Kennedy Space Center.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Background</td>
<td>1</td>
</tr>
<tr>
<td>II</td>
<td>Summary of Operations</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Operations</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Resources</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Aircraft Operations</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Principal Investigators</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Weather Forecasting &amp; Support</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Launch Support</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Departure Debriefings</td>
<td>6</td>
</tr>
<tr>
<td>III</td>
<td>Recommendations</td>
<td>7</td>
</tr>
<tr>
<td>IV</td>
<td>Acknowledgements</td>
<td>8</td>
</tr>
</tbody>
</table>

## ATTACHMENT

- A. TRIP 77 Siting
- B. Significant Data Collection Days (1977)
- C. Experimenters and Scientific Objectives
- D. Photo Documentation
- E. Guests/Visitors
SECTION I

BACKGROUND

TRIP 77 was a follow-on to the 1976 research program known either as Thunderstorm II or TRIP-76. The 1976 research period was from June 15 to August 13 and the 1977 period was about the same.

The significant difference in 1976 to 1977 was the ability of most of the experimenters to arrive early, set up their instruments and then remain at KSC longer in an active data collection mode. (Unfortunately, inclement weather for 1977 was not as good as for 1976, but there were many good data days that are noted in Attachment B. The sites selected by the experimenters are shown in Attachment A. Fifty-five (55) different sites were selected for the investigators’ instrumentation. These sites did not include the KSC field mill location; however, it did consider the twenty-five (25) rain buckets installed at the KSC field mill sites.

All of the investigators identified in Attachment C did submit letters identifying their support requirements, scientific objectives, numbers of personnel expected, etc. All these requirements were converted into security clearances, PRD/RD entries to Special Projects Document 081 Annex H. Approximately fifty pages of PRD/RD documentation had to be revised and/or new pages prepared.
SECTION II
SUMMARY OF OPERATIONS

I. OPERATIONS

The Technical Support (TS) Program Coordinator held a daily operations' briefing at 0900 in room 4296 of the Operations and Checkout Building (M7-355), KSC. During this period, the KSC Weather Office, mainly Mr. Gulick of NWS-NOAA, gave a post analysis of the previous day's weather, followed by the day's forecast and an outlook on weather conditions for the following day. The normal NOAA weather charts were used, complemented by the latest GOES satellite pictures, the latest rawinsonde sounding (usually taken at 0905Z) and the computer-derived thunderstorm probability forecasts associated with the sounding.

Following the weather briefing, discussions were held on what the experimenters had accomplished, and their plans for that day. The TS representative then scheduled the daily activity with KSC and the USAF, who in turn obtained our FAA flight clearance to perform aircraft operations over KSC and CCAFS.

II. RESOURCES

For TRIP 77, the following resources were provided to the investigators (all are John F. Kennedy services, except those noted with an asterisk(*) which were provided by USAF SAMTEC-1, AFETR & PAFB):

A. Field Mill data - magnetic tapes (3), hard copies contours.
B. Lightning detection and ranging (LDAR).
C. WSR72X Weather Radar. 33mm and polaroid photographs of scopes.
D. Daily weather summary.
E. *Rawinsonde data printouts. 2 daily.
F. NASA-6 airborne field mill data.

G. Photographic services (processing and dark room).

H. Wide-band and 3kHz data quality wire pairs.

I. Electrical power (KSC/CCAFS).

J. Loan pool services.

K. Equipment calibration.

L. Office space.

M. Telephone services in office spaces.

N. *Aircraft support at PAFB.

O. *Operational space at PAFB.

P. *Weather Information Network Display System (WINDS) data.

Q. GOES satellite photographs.

III. AIRCRAFT OPERATIONS

During the TRIP 77 experimental period, the following aircraft flew various data gathering sorties:

<table>
<thead>
<tr>
<th>Aircraft Arrived</th>
<th>Departed</th>
<th>User(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NASA-6 (C-45)</td>
<td>15 June</td>
<td>7 Sept *</td>
</tr>
<tr>
<td>NRL Navy S2D (USN)</td>
<td>5 July</td>
<td>29 July</td>
</tr>
<tr>
<td>Schweitzer 845A (ONR)</td>
<td>24 June</td>
<td>9 July</td>
</tr>
<tr>
<td>Bellanca Viking</td>
<td>18 July</td>
<td>29 July</td>
</tr>
<tr>
<td>Learjet Model 24B (NASA-705)</td>
<td>17 July</td>
<td>7 Sept *</td>
</tr>
<tr>
<td>T39B Saberliner (USAF)</td>
<td>4 Aug</td>
<td>30 Aug</td>
</tr>
</tbody>
</table>
*The NASA Learjet and the C-45 provided standby meteorological (lightning and thunderstorm reconnaissance) support for the Voyager launches.

Another interesting facet of the aircraft operations was the direct and nearby lightning strike simulations that were made on the TRIP 77 lightning configuration of the NASA 705 Learjet. Both capacitor banks of 200kV peak voltage and a Marx generator were used. These tests were conducted in Hangar 800 at Patrick Air Force Base with the gracious consent of the Base Operations Staff.

IV. PRINCIPAL INVESTIGATORS

Nineteen agencies (government/university) participated in TRIP 77. Seventeen of these experimenters were outside agencies, two were from the J. F. Kennedy Space Center and one participant operated from off-site. All experimenters and their scientific objectives are identified in Attachment C. At the peak of the measuring activity, eighty-two (82) visitors were supporting the program, excluding the KSC cadre. Attachment D of this report identifies the experimenters' equipment (in situ). Views of the various aircraft that participated in TRIP 77 are also included. All guests and visitors who attended TRIP 77 activities are shown on Attachment E.

V. WEATHER FORECASTING & SUPPORT

The KSC Weather Office provided daily weather briefings (5 days/week) to all experimenters and the necessary consultation services during the day. The office operated from 0630 to 2000, to provide overall coverage and data acquisition, particularly during thunderstorm periods which were normally from noon on. The
The Weather Office also supported some weekend operations, when predictions indicated a possible active weather day for Saturday or Sunday. The Weather Office staff was supplemented by the services of Sgt. James Murray (on loan from Detachment 11, 2nd Weather Squadron, Patrick Air Force Base, Florida) as a weather radar operator. NOAA arranged the employment of a summer student and we were fortunate to obtain graduate meteorologist Russell Stark. The services of these two individuals were invaluable, particularly for data acquisition and documentation during active storms and subsequently in the preparation of daily weather summaries dissemination to the experimenters.

VI. LAUNCH SUPPORT

From the 15th of June to the 7th of September, the services of NASA-6, the NASA 705 Learjet and T-39B Saberliner provided standby meteorological support for the following expendable vehicles/scientific satellite missions:

- Geosynchronous Operational Environmental Satellite (GOES-B) (U.S.) - 16 June
- Geosynchronous Meteorological Satellite (GSM) (Japan) - 14 July
- High Energy Astronomical Observatory (HEAO-1) (U.S.) - 12 Aug
- SIRIO (Italy) - 25 Aug
- Voyager 2 (U.S.) - 20 Aug
- Voyager 1 (U.S.) - 7 Sep
VII DEPARTURE DEBRIEFINGS

Each experimenter was personally interviewed by the Program Coordinator and Mr. Durrett of the KSC Lightning Committee. General comments were very favorable of the exceptional cooperative support provided by the J. F. Kennedy Space Center personnel. Many experimenters lauded the response time to accomplish their request, and the excellent weather briefings that were conducted. The KSC data was extremely useful to the majority of the experimenters. Data provided were:

A. Hard copies of field mill contouring.
B. Daily weather summaries.
C. WBAN-10 hourly weather observations from Cape weather station.
D. Printout of rawinsonde soundings.
E. Hard copies of LDAR plots.
F. WSR72X Radar Data (film & summaries).

A survey was made of all those principal investigators present to determine the interest for a TRIP 78. Eight investigators indicated an interest in returning to KSC for one more year of operational data, four expressed a maybe in returning for various reasons, and only one declined because of reassignment of duties. Other experimenters plan to gather data elsewhere in the U.S.
SECTION III
RECOMMENDATIONS

I. KSC management support the follow-on studies of the Thunderstorm Research International Program 1978 (TRIP-78) funding estimated at $100,000.

II. The New Mexico Tech rain gauges remain installed for data purposes to support rain rates at KSC for the year 1978. (Some data will be useful for MSBLS rain attenuation studies.)

III. Maintain some operational capability of field mill data measurement system and the LDAR equipment for CY 1978.
SECTION IV

ACKNOWLEDGEMENTS

I. The Federal Aviation Agency (ATC Miami and Air Traffic Group-PAFB)
for their favorable waivers for ballooning over KSC and their special air traffic
control considerations to the experimental aircraft used during this period.

II. The Air Force Eastern Test Range (AFETR) Detachment 1 and Patrick Air
Force Base (PAFB) for their cooperation in Range and Base support.

III. Those personnel at J. F. Kennedy Space Center who exhibited such a
cooperative attitude in supporting the scientists. Some of those services which
should be recognized are timing, communications, measuring, utilities and supply.
The scientists in their debriefings acknowledged your wonderful cooperation.

IV. The NOAA personnel in the KSC Weather Office for their outstanding forecasting,
data gathering and dissemination of data and weather information.

V. Mrs. Joan Bellamy, who provided the necessary gal-Friday support to the
Program Coordinator and to the multitude of experimenters and visitors who passed
through the Operations and Checkout Building during TRIP 77.
### SIGNIFICANT DATA COLLECTION DAYS (1977)*

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<thead>
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<th>DAY</th>
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<td>168</td>
<td>17 June</td>
<td>1632</td>
<td>1836</td>
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<tr>
<td></td>
<td></td>
<td>2009</td>
<td>2200</td>
</tr>
<tr>
<td>171</td>
<td>20 June</td>
<td>1640</td>
<td>1725</td>
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<tr>
<td></td>
<td></td>
<td>2005</td>
<td>2200</td>
</tr>
<tr>
<td>172</td>
<td>21 June</td>
<td>1704</td>
<td>1948</td>
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<td>2150</td>
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<td>181</td>
<td>30 June</td>
<td>1719</td>
<td>1930</td>
</tr>
<tr>
<td>182</td>
<td>1 July</td>
<td>1634</td>
<td>2150</td>
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<tr>
<td>186</td>
<td>5 July</td>
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<td>5 Aug</td>
<td>1855</td>
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<td>220</td>
<td>8 Aug</td>
<td>1840</td>
<td>0047 (9th)</td>
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<td>224</td>
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<td>1440</td>
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*Data Day - More than one experimenter collected data.*
## Experimenters and Scientific Objectives

<table>
<thead>
<tr>
<th>Experimenter</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arabian, D. A., Code W/A, NASA</td>
<td>a. Investigate various categories of thunderstorms in the vicinity of KSC</td>
</tr>
<tr>
<td>Lyndon B. Johnson Space Center</td>
<td>employing an instrumented Learjet.</td>
</tr>
<tr>
<td>Houston, TX. 77058</td>
<td></td>
</tr>
<tr>
<td>(713) 483-6233</td>
<td></td>
</tr>
<tr>
<td>Baum, Robert Lt. USAF, AF Flight</td>
<td>b. Conduct simulated lightning ground test utilizing the Learjet and</td>
</tr>
<tr>
<td>Dynamics Laboratory/FIS</td>
<td>electrostatic source provided by AFTDL, Wright-Patterson AFB, Ohio.</td>
</tr>
<tr>
<td>Wright Patterson AFB, OH 45433</td>
<td></td>
</tr>
<tr>
<td>(513) 255-5196/5439</td>
<td></td>
</tr>
<tr>
<td>Brook, Marx Dr., Research &amp;</td>
<td>a. Obtain magnetic field measurements of the nearby lightning environment</td>
</tr>
<tr>
<td>Development Division, New Mexico</td>
<td>employing an airborne platform.</td>
</tr>
<tr>
<td>Institute of Mining &amp; Technology</td>
<td></td>
</tr>
<tr>
<td>Socorro, NM 87801</td>
<td>b. Obtain measurement of skin currents and induced transients within the</td>
</tr>
<tr>
<td></td>
<td>aircraft while operating in a lightning environment.</td>
</tr>
<tr>
<td>(505) 835-5611</td>
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### Objectives

- **Objectives**
  - Investigate various categories of thunderstorms in the vicinity of KSC using an instrumented Learjet.
  - Conduct simulated lightning ground test utilizing the Learjet and electrostatic source provided by AFTDL, Wright-Patterson AFB, Ohio.
  - Obtain magnetic field measurements of the nearby lightning environment from an airborne platform.
  - Obtain measurement of skin currents and induced transients within the aircraft while operating in a lightning environment.
  - Obtain a correlation between airborne and ground lightning test measurements.
  - Make electrostatic field mill measurements over the Cape Kennedy network for calibration of the ground network.
  - Location of lightning charge "centers" from time-resolved multistation electric field change measurements, and correlation of these results with storm physical structure as determined by multi-Doppler radar measurements of wind field, fast scanning radar measurements of cloud reflectivity, and in-cloud measurements of cloud microphysical and electrical structure. Also, correlation of the charge center results with the results obtained from LDAR, the electric field mill network, and lightning channel reconstruction using thunder measurements.
  - Study of the evolution of cloud reflectivity structure using a fast scanning X-band surveillance radar. Measurement of reflectivity intensification rates and the relationship between echo intensification and lightning occurrence, correlated with the raingage network measurements.
  - Lightning fine structure measurements using a moving film lightning camera, and, as time permits, wideband electric field and radiation measurements.
EXPERIMENTER (CONT'D)

Few, Arthur A. Jr. Dr.
Dept. of Space Physics & Astronomy
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(713) 527-8101 X3601

Kalafus, Rudolph M., Dr.
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Kasemir, Heinz W., Dr.
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Environmental Research Laboratories
Boulder, CO. 80302
(303) 499-1000 X6249

Krider, E. F., Dr.
Institute of Atmospheric Physics
University of Arizona
Tucson, AZ 85721
(602) 884-1329

OBJECTIVES (CONT'D)

a. Obtain data on the location and orientation of all major lightning channels both inside and outside the cloud throughout the time development of marine air-mass thunderstorm at KSC.

b. Obtain data on the location and geometry of the charged cloud regions supplying charge to each lightning flash in the KSC thunderstorms studied.

c. Obtain data on nature and explanation of the infrasonic emissions from thunderclouds associated with electrical discharges.

d. Obtain vertical profiles of temperature and corona currents inside thunderclouds.

e. Correlate acoustic methods of lightning and source location with electromagnetic and multi-station electrostatic techniques.

f. Correlate electric fields inside thunderclouds with fields measured at the surface and on aircraft outside the thunderclouds.

g. Correlate regions of lightning activity and charge generation with thunderstorm dynamical data and with the thunderstorm microphysical data.

(See Marrero, P. J. for objectives).

a. Using aircraft, determine the electric field and space charge distribution inside electrified convective clouds in the Florida area, and correlate the charge centers with meteorological parameters.

a. Study the overall evolution of lightning activity at the NASA Kennedy Space Center using the KSC field mill network and other sensors. The frequency of lightning discharges, the fraction of cloud-to-ground discharges, the fraction of discharges containing continuing currents, and the number of return strokes in cloud-to-ground discharges all will be measured as a function of time during summer storms.
3.

b. Study the physical characteristics of lightning stepped-leader and return stroke currents using fast time-resolved measurements of the electric and magnetic fields produced by discharges at KSC. This experiment is part of a joint multi-station experiment with Dr. Martin A. Uman and his group at the University of Florida. Return stroke propagation speeds will be measured photoelectrically, and these speeds will be used to test models of how return stroke currents propagate up the leader channels.

c. Study sources of atmospheric radio noise in the HF and VHF bands using time-resolved electric field measurements with correlated sferics records.

a. LDAR, a Lightning Detection and Ranging System, will be operated at KSC. The space-time history of the lightning discharge process will be mapped by measuring the time of arrival (at 6 receiving stations) of lightning produced RF pulses in the 30 to 50 MHz frequency range.

1. To locate electrically active areas of a cloud and map the space-time history of the electrical discharges.

2. To determine the physical relationship between electrically active areas and rain areas of a cloud.

3. To detect and locate lightning strikes to ground.

4. To gather additional evidence that the observation that VHF radiation ceases just prior to the step leader making contact with the ground and resumes after the return stroke has been established.

5. To map lightning ground strike locations relative to electrical active portion of the cloud.

a. The general purpose of this research program is to examine the structure of waveforms radiated from lightning for characteristics which are indicative of storm type. In particular, to determine whether or not tornadic bearing storms can be identified on the basis of the RF radiation associated with the storm system.

b. The specific objective at KSC will be to collect waveforms at frequencies from HF-UHF in conjunction with other monitoring of the lightning in order to associate the RF structure of the lightning with physical parameters of the lightning flash and with the dynamics of the storm.
EXPERIMENTER (CONT'D)

Lhermitte, Roger, Dr.
School of Marine & Atmospheric Science
Div. of Atmospheric Science
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P. O. Box 249115
Coral Gables, Fl. 33124
(305) 350-7491

Mangold, Vernon
A.F. Flight Dynamics Laboratory/FE5
Wright-Patterson AFB, OH 45433
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Marrero, Peter J.
NASA Code EC32
George C. Marshall Space Flight Center
Marshall Space Flight Center, AL
35812
(205) 453-1597

Moore, Charles B., Prof.
Department of Physics
New Mexico Institute of Mining & Technology
Socorro, NM 87801
(505) 835-5423

OBJECTIVES (CONT'D)

a. Study of the three dimensional structure of motion and radar reflectivity fields inside thunderstorms. Special attention will be given (but not limited to) to the study of strong updrafts or downdraft observed by the system inside convective storms as related to the distribution and evolution of electric charges in the storms, or the occurrence of lightning, which will be observed.

b. Flight evaluation of a lightning detector instrument package (Stormscope). Test bed will be a T-39-B aircraft equipped with a new digital weather radar (Bendix RDR-1300) and transient digitizer system (WP-2222) for evaluation of the Stormscope.

c. A ground station will evaluate a newly developed narrowband UV optical densitometer system & ground testing of optical charges in air density (wind) and/or rainfall as a function of lightning activity.

d. Laser triggering of natural lightning using a high peak power laser (4x10^8 watts) and suitable optics for triggering and/or providing a convenient path for lightning discharge.

e. Utilize a Pulsed Laser Doppler System to prove the feasibility to measure the gust from velocities in the non-precipitous regions of a storm and measure the associated wind shears. The goal is to collect data on the penetration of the CO2 laser beam into the storm and compare this data with standard wind anemometers on a tower, weather and doppler radars.

f. Characterization of 'sea coastal' thunderclouds.

g. Study of relations and differences between electric fields at the earth's surface with those within active thunderclouds.

h. Study of precipitation formation and development in Floridian thunderclouds with special attention given to the precipitation in warm regions of the cloud.

i. Determination of charge and electric field distributions aloft in developing Floridian thunderclouds.

j. Cooperative study of relations between rainfall and lightning over KSC.
OBJECTIVES (CONT'D)

See Arabian for objectives.

a. Measure the return stroke velocities near the ground and simultaneously record the electric and magnetic fields (Uman, Drider). From these data it may be possible to calculate the electric current flowing in cloud-to-ground return strokes in the first few tens of microseconds.

a. Evaluate WINDS data to compute patterns of divergence and convergence and compare the strength of these fields with lightning frequency. The hypothesis is that strength of convergency is a measure of thunderstorm activity.

See Lennon for objectives.

a. An S-band radiometer will be used on a narrow-beam, steerable antenna to measure the radiation from clouds and thunderstorms. The major objective of this program is to ascertain whether the presence of cloud electrification can be detected in this way. If this is possible, an attempt will be made by collaborating with other investigators to determine those electrical processes or conditions that resulted in remote detection. Of particular interest are electric fields at the ground and aloft, precipitation and lightning. In addition, the radiometric data will be correlated with radar data.

See Stubbs for objectives.
EXPERIMENTER (CONT'D)

Stubbs, Donald  
NASA Code DL-NED  
John F. Kennedy Space Center  
Kennedy Space Center, FL 32899  
(305) 867-4548

Taylor, William, Dr.  
National Severe Storms Lab.  
NOAA-ERL  
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Norman, OK 73069  
(405) 329-0388

Turman, Bobby N., Capt. USAF  
Code TFE  
Hdq. 1035th Technical Operations  
Group  
Patrick AFB, FL 32925  
(305) 494-2924

Uman, Martin, Dr.  
Dept. of Electrical Engr.  
College of Engineering  
University of Florida  
Gainesville, FL 32611  
(813) 392-0911

OBJECTIVES (CONT'D)

a. Lightning Triggering at KSC: The basic rationale for triggering lightning at the John F. Kennedy Space Center (KSC) is to control lightning and increase the number of strokes to a structure in a known time frame to quickly verify the lightning protection of the structure and associated ground support equipment (GSE) with natural lightning. In addition, natural lightning currents could be used to verify the lightning protection of flight hardware and other components, and even full-scale aerospace vehicles. Natural lightning possesses high voltage and energies not available from simulators, and this makes it very useful for final verification testing of the lightning protection of large structures, or components that include composite materials.

a. Field measurements of the spacetime history of intracloud discharges superimposed on Doppler radar motion fields and precipitation structure.

b. Inference of discharge characteristics from observed quantities.

c. Contribute to knowledge of physical processes acting in charge separation and discharge.

a. To measure indirectly time-dependent optical transmission properties of clouds using two ground stations, separated by one km.

a. Basic objective is to measure return-stroke current waveshapes by operating fast electric and magnetic field antennas at KSC and Gainesville.

b. Operation of two TV systems to accumulate information on Lightning location, time of occurrence, strokes per flash, etc.
NMIT field change meas. inst. typical

NMIT field change calibration inst. (ANTENNA SITE)

NMIT central recording
NOAA ERL RUST
RADIOMETER INST.
CIF ANTENNA SITE
radiometer controls
RICE UNIVERSITY
FEW

microphone typical - 3 sites

recording site (WX SUB STA. B)
storm scope/laser control van

AFFDL, WPAFB, OH. MANGOLD (fire & rescue area)

vans

stormscope

laser

grounding tower & laser reflector
LIGHTNING A/C STRIKE TEST
JSC-NASA/MANGOLD
hgr. 800
PAFB
PULSED LASER DOPPLER SYSTEM

CO₂ laser

400cyc. generator
PULSED LASER DOPPLER SYSTEM

laser target @ UCS-16

wind recording eq. @ 150 meter tower

interior recording inst.

NASA-6

hanger 751
# GUESTS/VISITORS

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution/Address</th>
<th>Dates</th>
</tr>
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<tbody>
<tr>
<td>Anderson, Ralph, Dr.</td>
<td>Council for Scientific &amp; Industrial Research National Electrical Engineering Research Institute P. O. Box 395 Pretoria, 0001 South Africa</td>
<td>7/19-28/77</td>
</tr>
<tr>
<td>Andra, Claude</td>
<td>Establissement D'Etudes ETDE Recherches Meteorologiques (EERM) Meteorologie Nationale 73-77 Rue De Sevres 92100 Boulogne, France</td>
<td>7/6/77</td>
</tr>
<tr>
<td>Arnold, Roy, Dr.</td>
<td>University of Mississippi Oxford, Mississippi</td>
<td>7/6-8/77</td>
</tr>
<tr>
<td>Berger, Karl, Dr. (Consultant)</td>
<td>GSTAD STR 31 CH 8702, Zollikon, Switzerland</td>
<td>7/19-28/77</td>
</tr>
<tr>
<td>Blair, James</td>
<td>National Geographic Society 17th &amp; M Streets, N.W. Washington, D. C. 20036</td>
<td>8/1-11/77</td>
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<td>Boulay, Jeal Louis</td>
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6/16-8/3/77
8/1-2/77
6/26-7/8/77
7/19-29/77
7/19-22/77
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7/7-15/77
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