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Measured Electric Field Intensities Near Electrical Cloud Discharges Detected by the Kennedy Space Center's Lightning Detection and Ranging System, LDAR

(NASA-CR-154630) MEASURED ELECTRIC FIELD INTENSITIES NEAR ELECTRIC CLOUD DISCHARGES DETECTED BY THE KENNEDY SPACE CENTER'S LIGHTNING DETECTION AND RANGING SYSTEM, LDAR (Federal Electric Corp., Cocoa Beach, Fla.) G3/47 N79-20573 Unclas 17259

Dr. Horst A. Poehler

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MEASURED ELECTRIC FIELD INTENSITIES NEAR ELECTRICAL CLOUD DISCHARGES DETECTED BY THE KENNEDY SPACE CENTER'S LIGHTNING DETECTION AND RANGING SYSTEM, LDAR

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Federal Electric Corporation
RF Systems Branch
Kennedy Space Center

February 1977

APPROVAL

MEASURED ELECTRIC FIELD INTENSITIES NEAR ELECTRICAL CLOUD DISCHARGES DETECTED BY THE KENNEDY SPACE CENTER'S LIGHTNING DETECTION AND RANGING SYSTEM, LDAR

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SUMMARY

For a summer thunderstorm, for which simultaneous, airborne electric field measurements and Lightning Detection and Ranging (LDAR) System data was available, measurements were coordinated to present a picture of the electric field intensity near cloud electrical discharges detected by the LDAR System. Radar precipitation echos from NOAA's 10 cm weather radar and measured airborne electric field intensities have been superimposed on LDAR PPI plots to present a coordinated data picture of thunderstorm activity.

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I. INTRODUCTION

Numerous agencies cooperated in the Thunderstorm II Project, held at the Kennedy Space Center in the summer of 1976. Participating agencies sent their specialized equipment and their investigators to KSC to conduct simultaneous measurements of thunderstorm characteristics. Among others, the participants included Johnson Space Center (JSC) personnel who conducted airborne electrical field measurements, and Kennedy Space Center personnel who operated the KSC Lightning Detection and Ranging System, LDAR, to detect, and determine the position of, electrical discharges in the thunderstorm clouds.

Considerable data was collected by both agencies. Of particular interest, however, is data for those time periods for which both systems were operational for the same storm. This occured on July 30, 1976.

Electric field and LDAR data for this storm will be presented, and a combined picture will be given to illustrate the levels of airborne electric field intensities in the neighborhood of lightning discharges. While electric field and LDAR data have been presented before, a unified picture, showing the electric field intensities near electrical discharges in the sky, has not previously been available.

II. DISCUSSION OF THE DATA

1. Airborne Electric Field Measurement

Airborne electric field intensities were measured by a system developed by the Stanford Research Institute. A detailed discussion of the measurements and of the results can be found in Reference (1). Electric field measurements were made by field mills mounted on the external surface of the

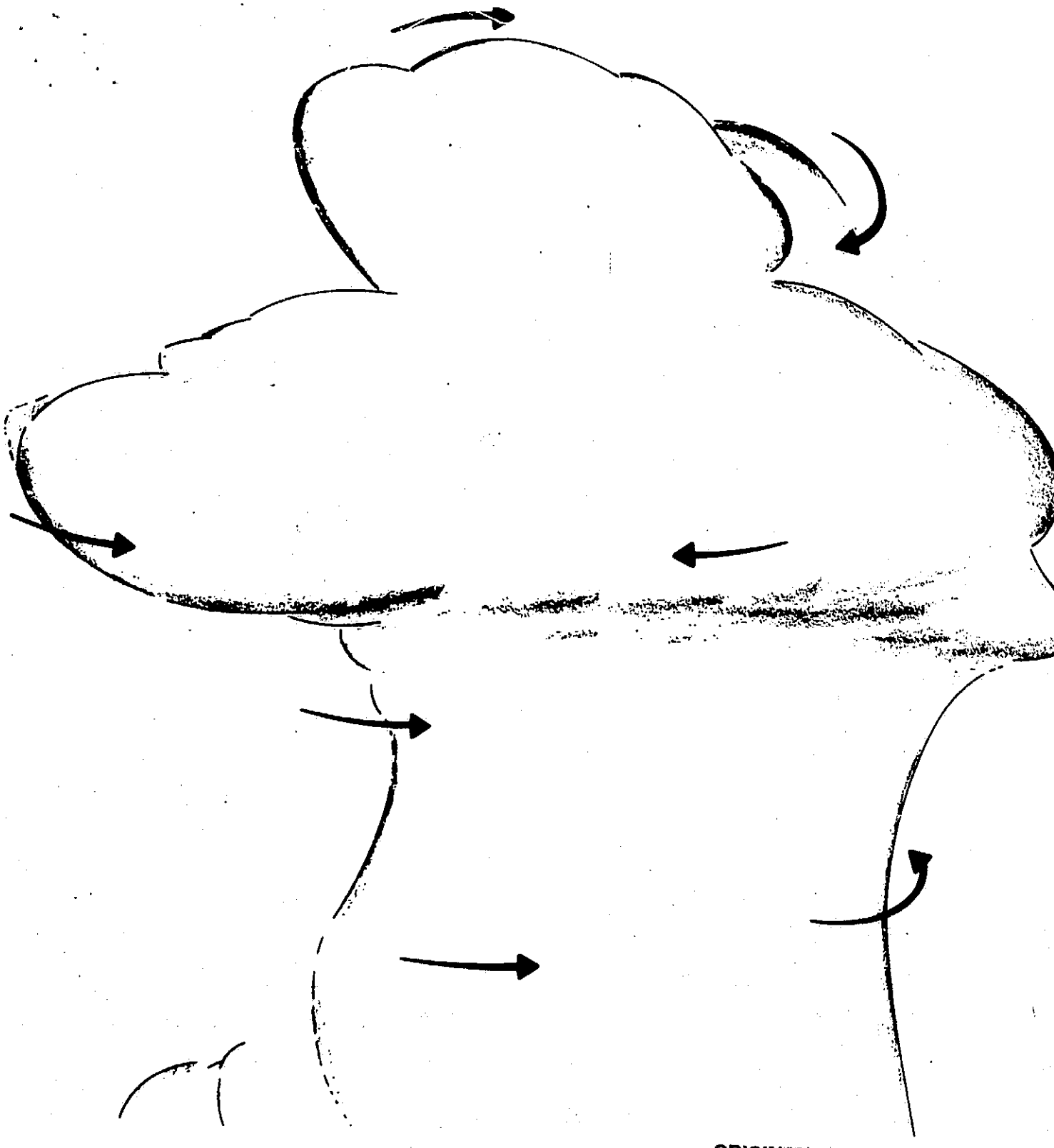

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FIGURE 1. TYPICAL FLIGHT PATH FOR INVESTIGATION OF ANVIL
(From Ref. (1))

aircraft, and so installed that the ambient electric field components E_X, E_Y, and E_Z could be located in a coordinate system formed along the aircraft flight path, with the aircraft at the origin of the system. Field-mill readings were recorded on a Visicorder strip chart recorder. Pre flight calibrations were conducted prior to each flight.

The prime object of each data flight was to locate and acquire a well isolated anvil-type cumulonimbus cloud. Typically an attempt was made to fly through the cloud anvil starting at the outer edges and moving progressively in towards the core of the cloud. Finally the cloud was "boxed" by flying around the outer edges. A typical investigative flight path is shown in Figure 1, as given in Reference (1).

Of the twenty five airborne field-measurement flights, only three were made within the operating range of the LDAR system. The other flights were made further than 40 miles out, investigating clouds near Miami, Lake Okeechobee, Vero Beach, Daytona Beach, Palm Beach, and Sarasota. Simultaneous LDAR measurements were available for only two (July 19 and July 30) of the three flights made within the operating range of the LDAR system. A lack of sufficient time-indexed data prevents a meaningful comparison of the July 19 data. Our report, therefore, is confined to a discussion of the July 30 data.

We are indebted to Mr. Cecil G. Jenkins of the Johnson Space Center Resident Office at the Kennedy Space Center for supplying us with the raw, and with the reduced electric field intensity data, that was used in this report.

2. Location of Electrical Discharges by the LDAR System

The LDAR system locates the position of electrical discharges in the clouds from the time of arrival of the pulsed RF radiation emitted by the discharge. The LDAR system operates in the frequency band of 30-50 Mhz, and uses a central receiving station, together with four outlying receiving stations, each at a separation of some 8 km from the central station. LDAR is a near real-time system that has the capability of detecting ten data points per second and recording these on digital tape. An even higher rate of 300 data points per second is available by real time, wide-band recording of the incoming signals, and post flight analysis.

The system has been described in detail by Lennon[2,3]. An analysis of the accuracy of the system is given by Poehler[4].

3. Combined Data Presentation

During the storm of July 30, 1976, the aircraft made ten passes at elevations between 39,000 and 42,000 feet. The plane explored the anvil and purposely avoided the cores of the storm. Figure 2 shows that the plane explored the upper portion of the storm, and shows some electric field levels measured during the ten passes.

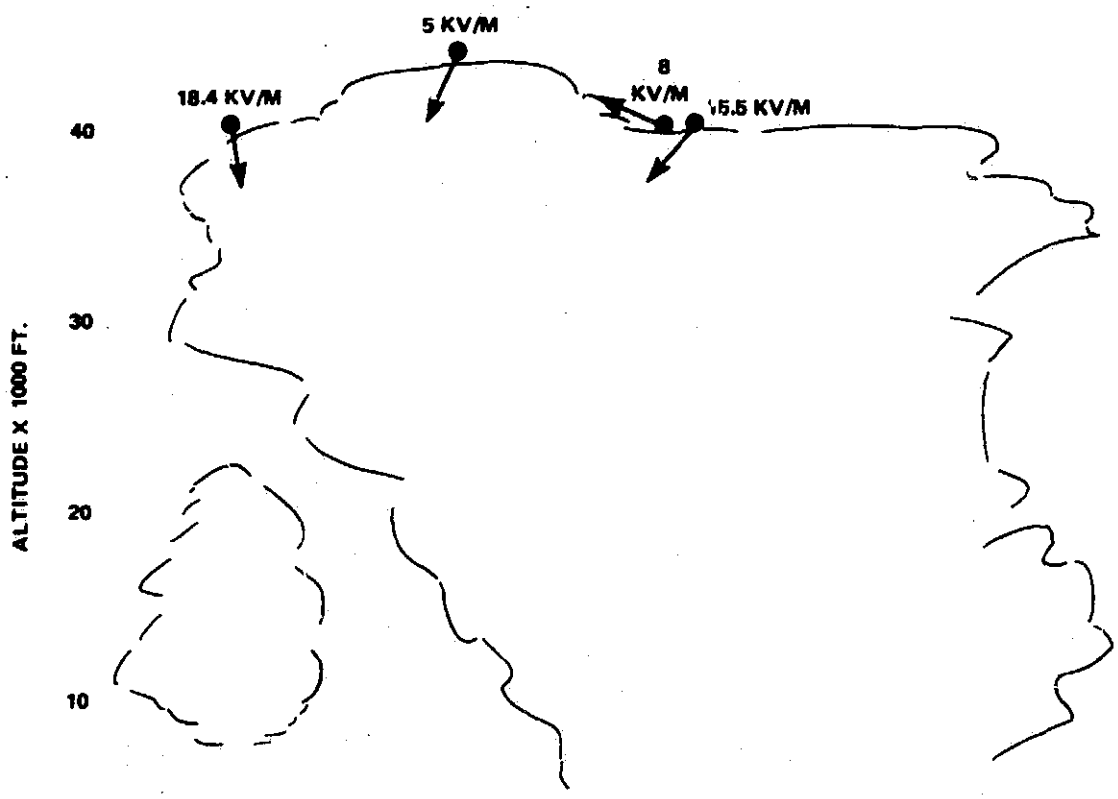


FIGURE 2. VERTICAL CLOUD STRUCTURE
JULY 30, 1976, 1900-1920 GMT (From Ref. (1))

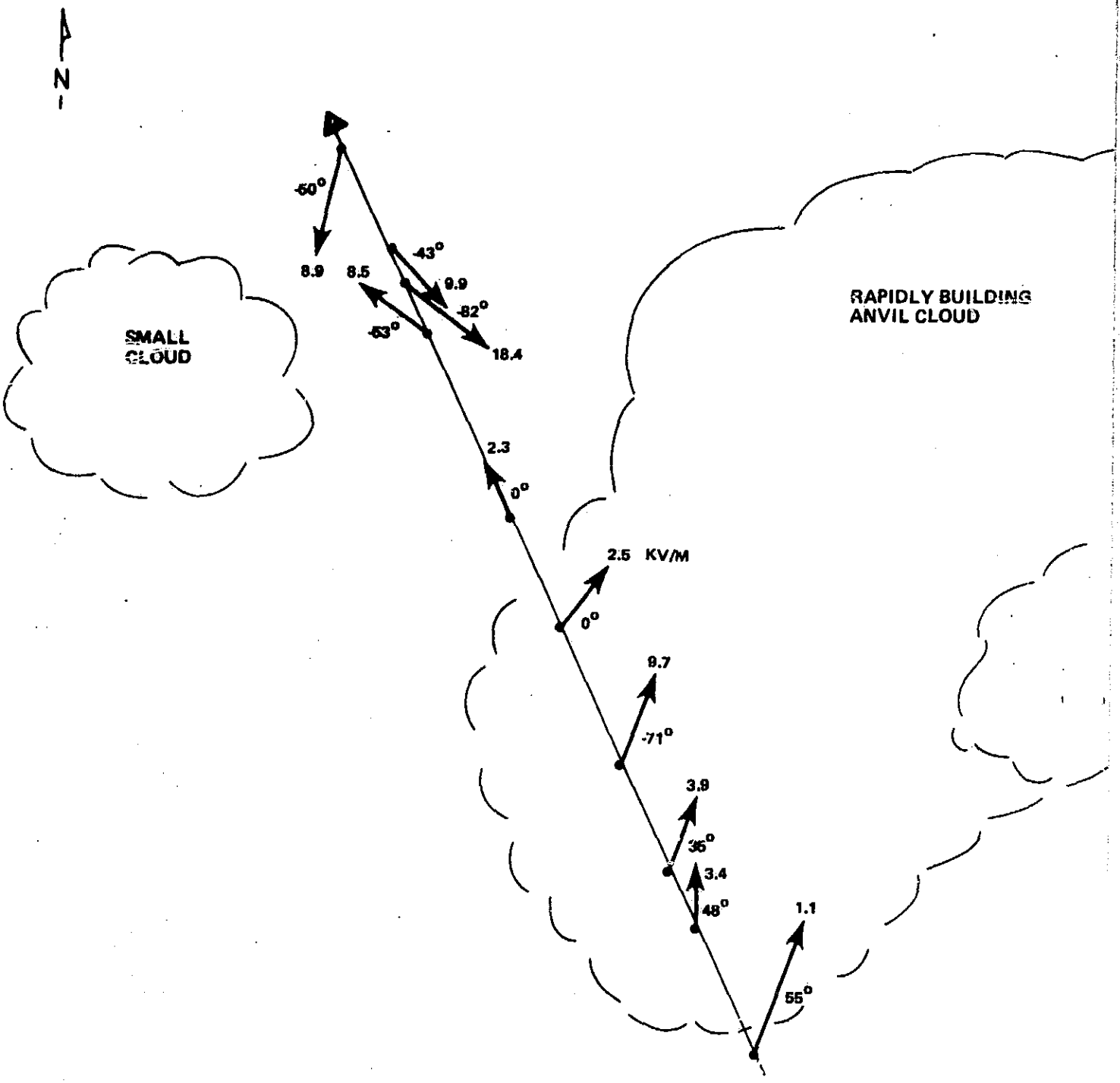
Pass No. 1

In Figure 3 we present the measured electric field intensity along Pass No. 1, together with a sketch of the cloud structure, as sketched by plane personnel from visual observations. While the flight angle and flight length are highly accurate, the dimensions (and especially the depth) of the clouds are very approximate, since they are not based on measurement but on visual estimates.

In Figure 4 we present the LDAR plot corresponding to Pass No. 1, showing the range, azimuth, and elevation of the electrical discharges in the clouds, during the period 1905 to 1909 GMT.

The plane's track has been carefully sketched in and is shown in blue. In addition the position of the clouds, as given in Figure 3, have been sketched. As mentioned earlier all the electric field intensities, plane track, and cloud data has been supplied to us by Mr. Cecil Jenkins of the JSC Resident Office at KSC.

Along the flight path the electric field intensity is indicated. The magnitude of the electric field intensity vector is indicated by a numeric in kv/m. The direction of the vector in the horizontal plane is indicated by its orientation on the plot relative to north. The direction of the vector in the vertical plane is given by its declination in degrees. A positive angle indicates an upward direction, and a negative angle is used to indicate a downward direction. For example, a vector having a +90 degree declination would be pointing straight up, and would have no horizontal component. A vector with a 45 degree declination would be pointing upwards at 45 degrees, and would have equal horizontal and vertical components. The direction of



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ELECTRIC FIELD IN KV/M
DECLINATION IN DEGREES

FIGURE 3. PASS 1, HEADING 335°, ALTITUDE, 39,200 FT (From Ref. (1))

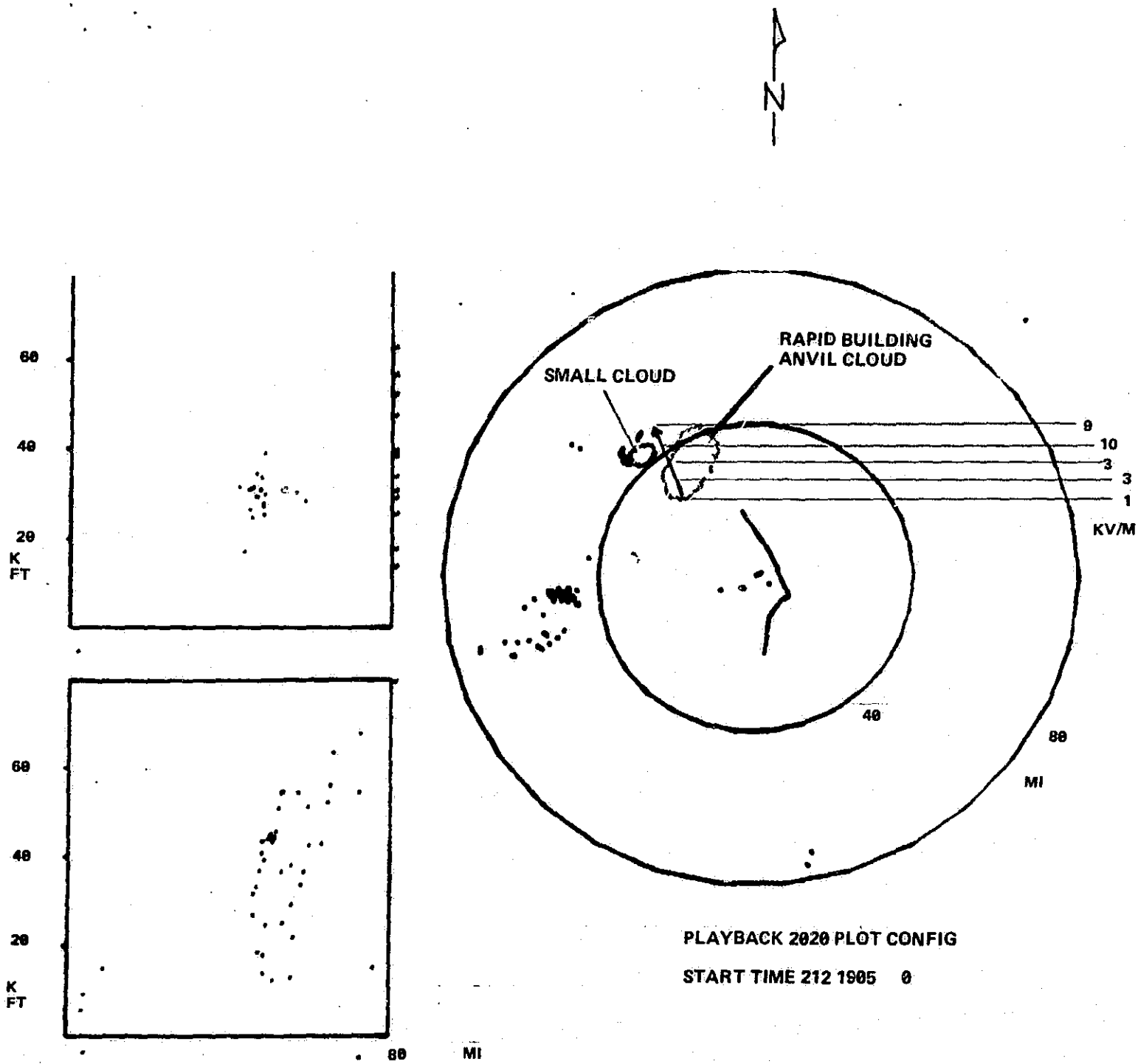

FIGURE 4. LDAR PLOT, PASS 1

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the electric field intensity vector is taken as the direction of the force exerted by the field on a positive charge.

Note that the field strength level is low (less than 4 kv/m) within the anvil, and that no LDAR discharges are shown within the anvil. However, LDAR discharges can be seen in the region of the "Small Cloud".

Near the "Small Cloud" the electric field increases to a range of 8.5 to 18.4 kv/m. Comparison with the LDAR plot shows LDAR data points (electrical discharges in the clouds) within and to the left of the "Small Cloud"

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Pass No. 2

Pass No. 2 is shown in Figure 5, along with the measured electric field in kv/m, declination in degrees, and a sketch of the cloud structure. The corresponding LDAR plot, covering the time period 1912-1914 GMT is shown in Figure 6. The position of the "Anvil" and "New Cloud Building" shown in Figure 5, has been added to the LDAR plot. Note that LDAR shows two electrical storms in progress, one in the north and one in the northwest, both at approximately 40 miles. Two elevation plots are shown at the left. The upper plot gives the elevation of data points in the upper half of the LDAR plot, that is for azimuth less than 90 degrees, and for azimuths greater than 270 degrees. The lower plot gives the elevation for data points in the lower half of the LDAR plot.

Observe that no LDAR discharges are shown in the anvil, where the electrical field gradient is no higher than 4 kv/m.

In Figure 7, we show copies of the 1930 GMT PPI radar plot sketched by the NOAA Daytona Beach 10 cm weather radar personnel. Precipitation echoes have been outlined, and the centers of activity have been marked ++ symbols. Here ++ designates a 30 db return, which corresponds to a rainfall of 1-2 inches/hour, x designates a 36 db return, which corresponds to a rainfall of greater than 2 inches/hour. Both correspond to centers of thunderstorm activity, the x being the more intense.

Normally radar PPI plots are made once per hour. The radar plot of 1930 is the plot that comes closest to our data period 1912 to 1943, GMT. Films of the PPI displays are also made, and are available on special request. They have been requested. When they arrive, they will give us a more accurate

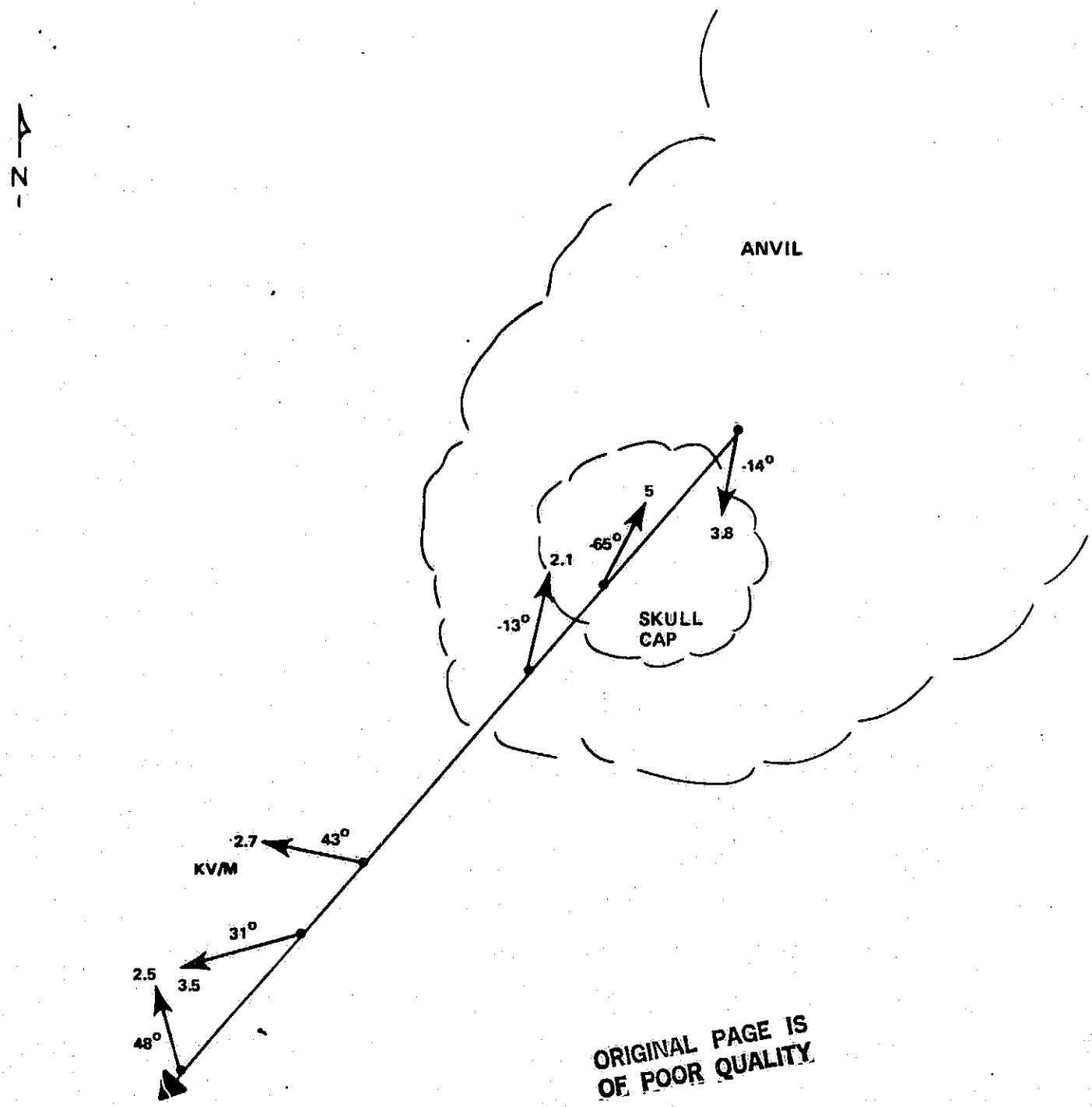

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FIGURE 5. PASS NO. 2, HEADING 220°, ALTITUDE 42,900 FT.

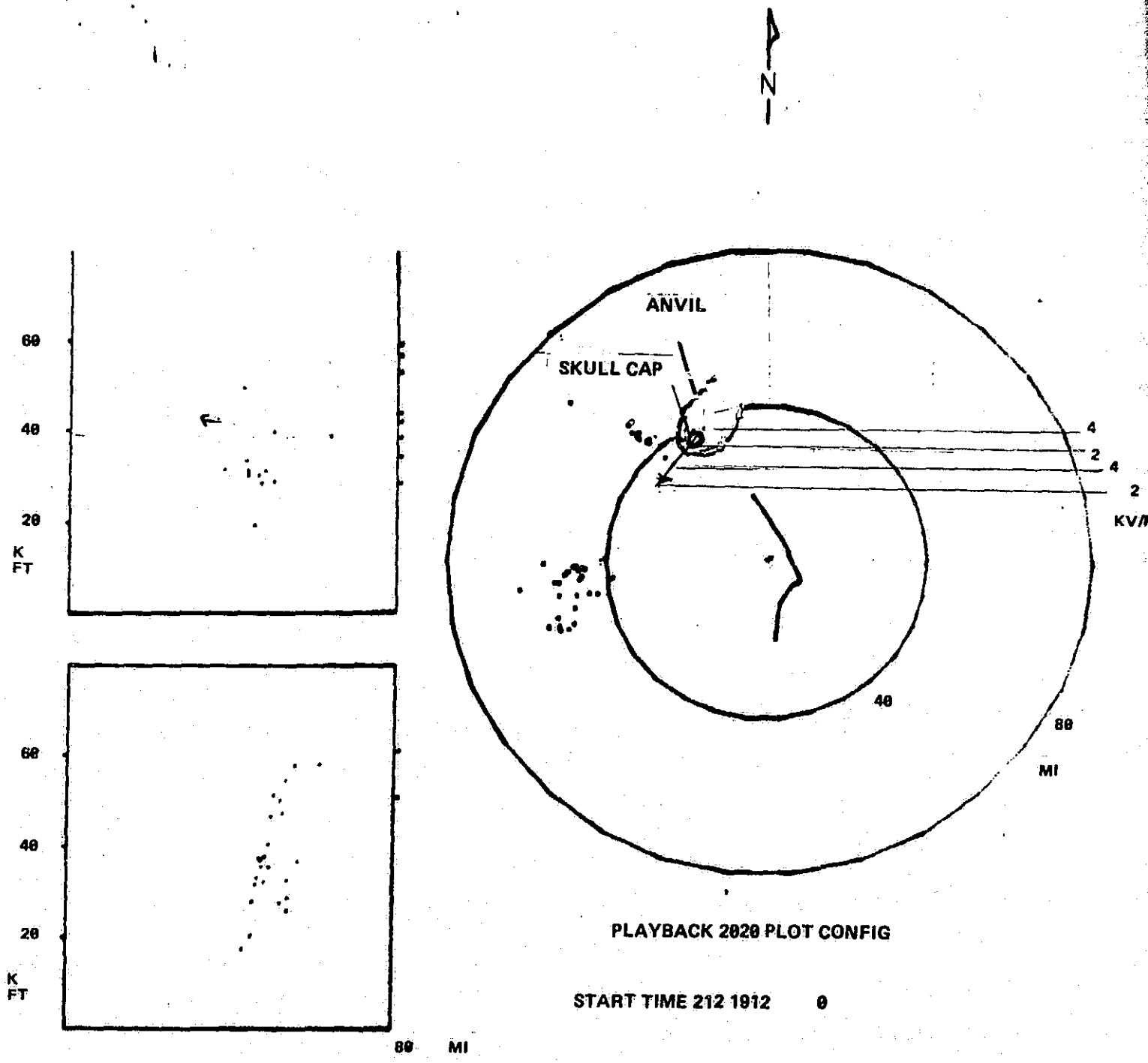

FIGURE 6. LDAR Plot, Pass No. 2

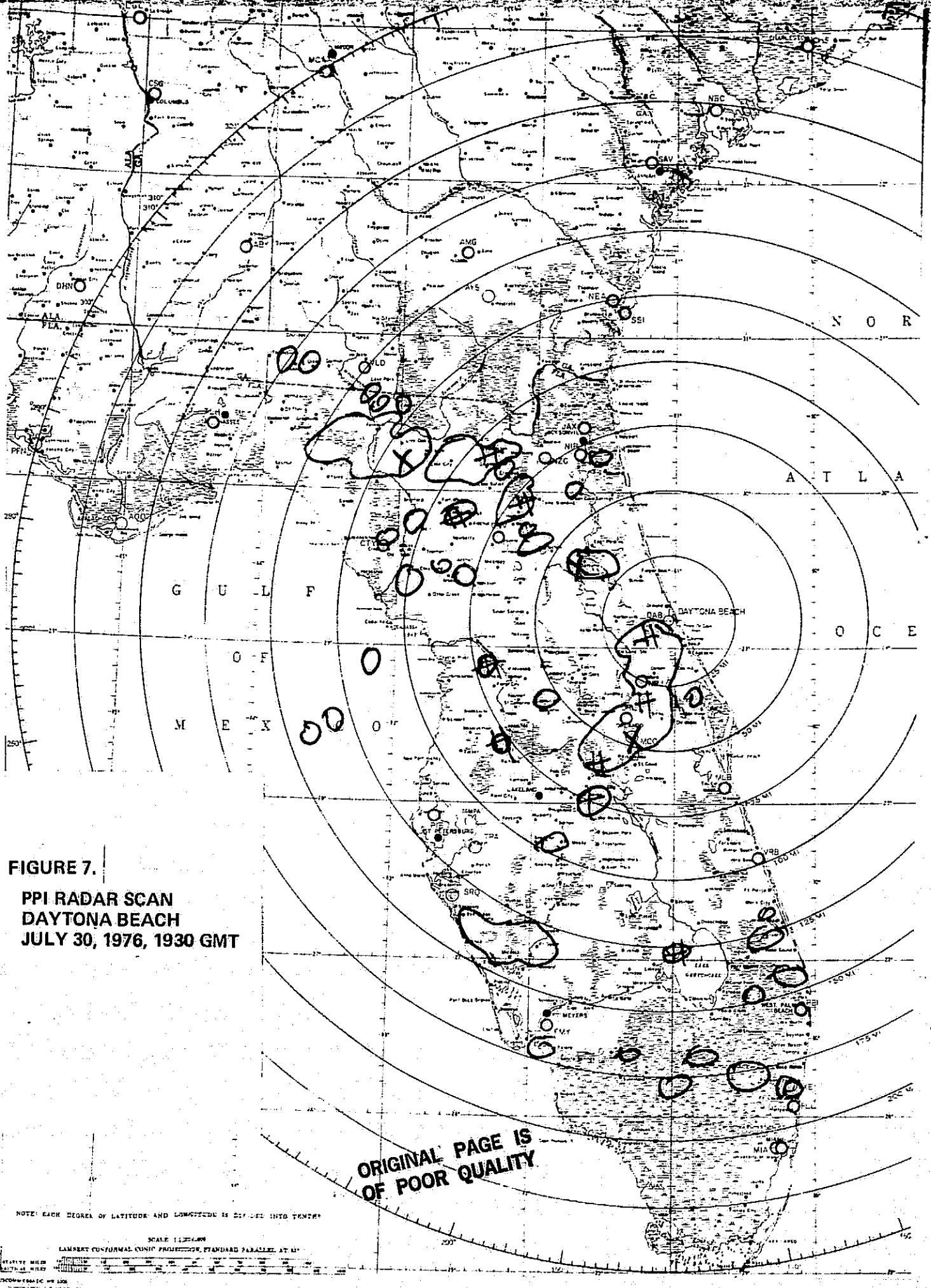

FIGURE 7.

PPI RADAR SCAN
DAYTONA BEACH
JULY 30, 1976, 1930 GMT

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picture. Unfortunately they have not arrived at this writing.

The precipitation echos of Figure 7 have been sketched on the LDAR plot of Figure 8. In comparing Figures 7 and 8 we must take into account the fact that the scale shown on Figure 7 is in nautical miles, and the scale shown in the LDAR plot of Figure 8 is in statute miles, further 1 nautical mile equals 1.1508 statute miles. Note also that the radar equal-range circles are centered about Daytona Beach, whereas the LDAR's equal-range circles are centered about the A-2 LDAR site at 28° 32' 28.920" latitude, and 80° 38' 38.498" longitude.

The precipitation echo shown in Figure 8 explains the two thunderstorms shown by the LDAR in Figures 4 and 6. The radar return also shows that the airborne electric field measurements were made outside of the cores of the thunderstorms in progress, in keeping with the low (2-4 kv/m) electric field strength observed along the plane's track.

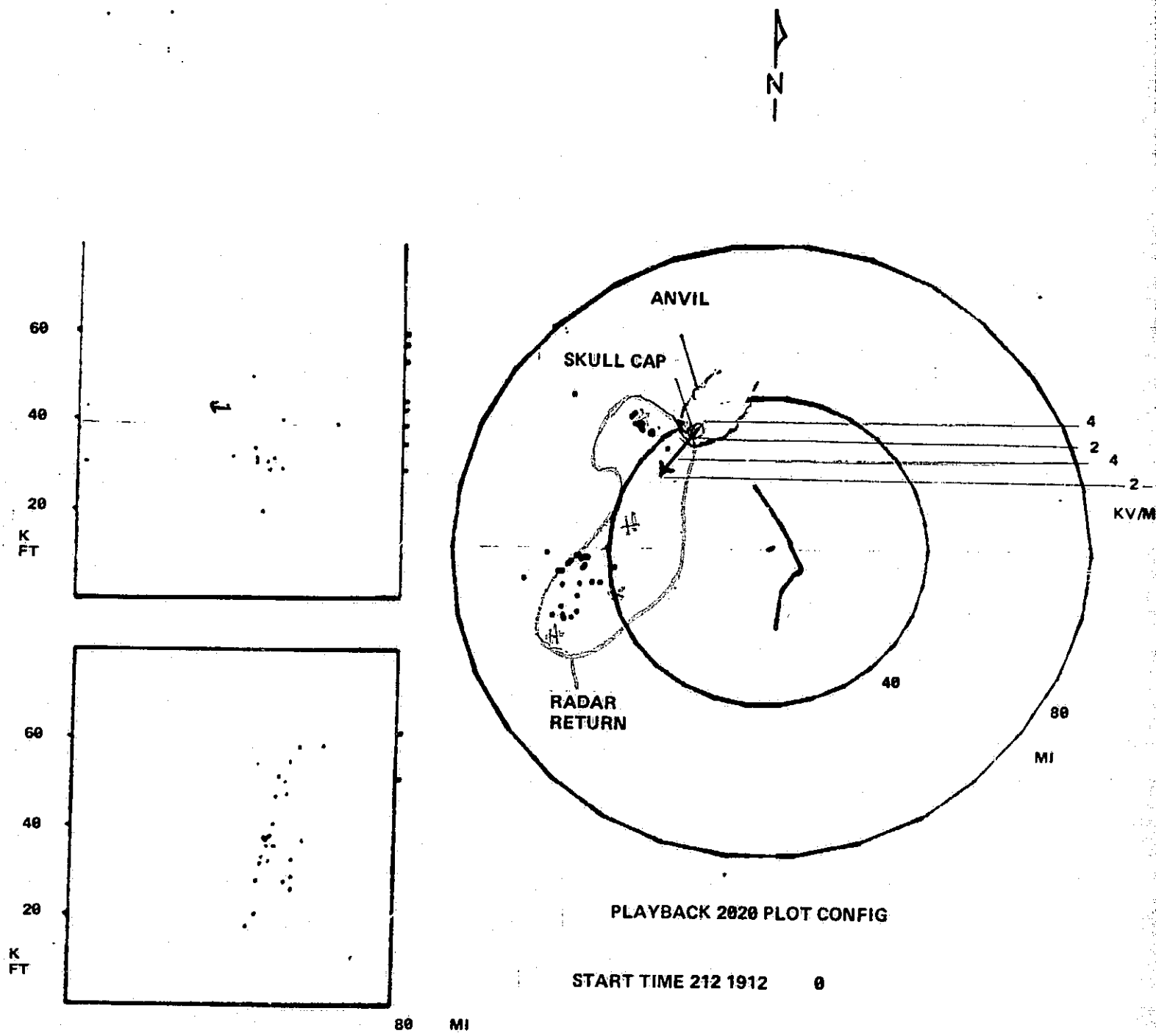

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FIGURE 8. RADAR PRECIPITATION ECHO ADDED TO LDAR PLOT, PASS 2

Pass No. 3

Pass No. 3 is shown in Figure 9, along with the measured values of electric field in kv/m, declination in degrees, and a sketch of the surrounding cloud structure.

The corresponding LDAR plot, covering the time period 1920-1923 GMT is shown in Figure 10. The position of the "Anvil" and of the "Skull Cap" shown in Figure 9 has been added to the LDAR plot. LDAR data points, indicating electrical discharges, are clustered near the skull cap. Note in particular that six of the eight field strength vectors lie along a line to the skull cap, indicating a high charge concentration in that region. The highest field reading is found next to the skull cap.

Only one LDAR data point is shown in the anvil region.

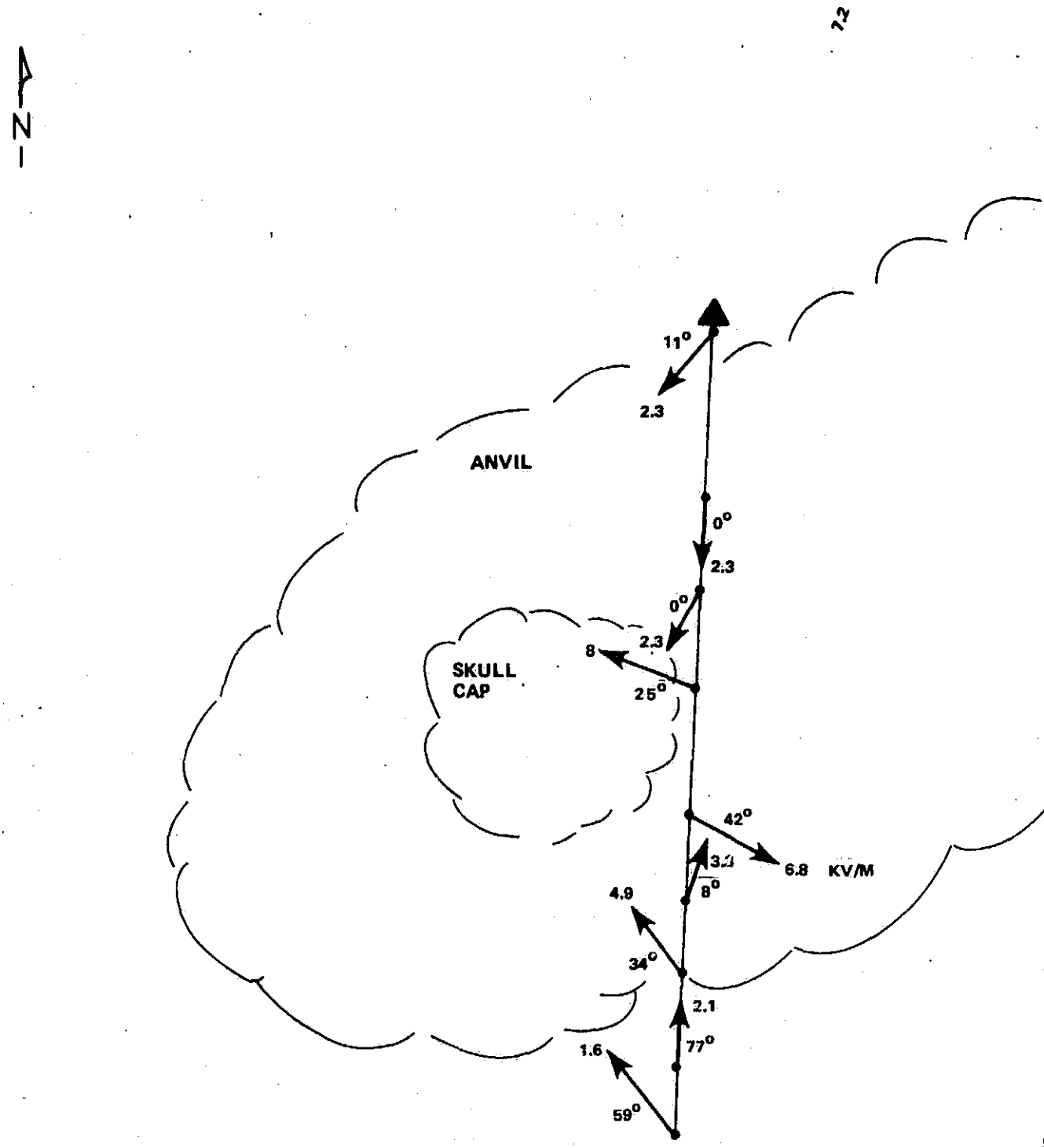

FIGURE 9. PASS NO. 3, HEADING 02°, ALTITUDE 39,200 FT.

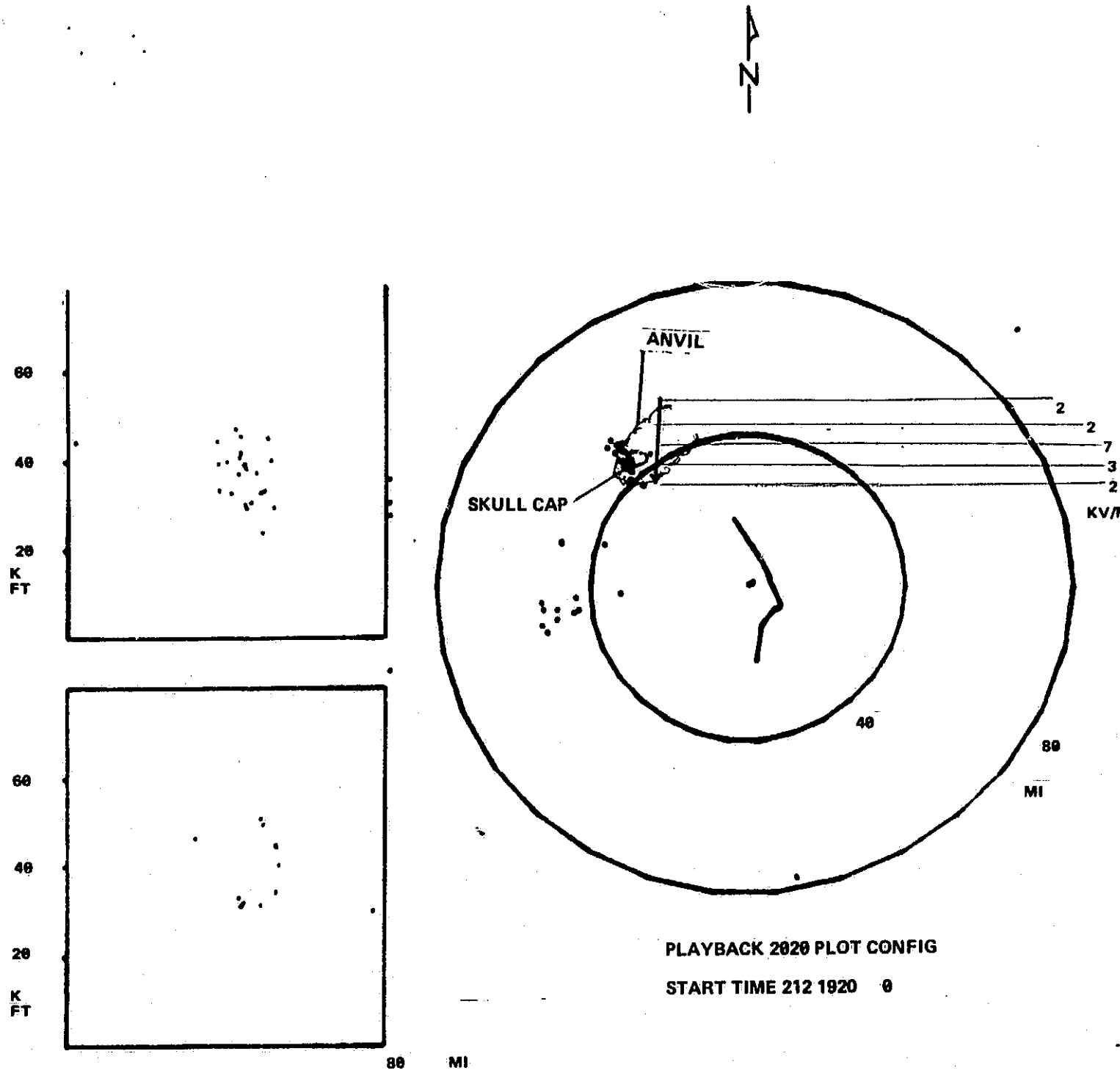

FIGURE 10. LDAR PLOT, PASS NO. 3

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Pass No. 4

Pass No. 4 is shown in Figure 11, along with the measured values of the electric field in kv/m, declination in degrees, and a sketch of the surrounding cloud structure.

The corresponding LDAR plot, covering the time period 1923-1927 GMT is shown in Figure 12. The position of the "Anvil" and of the "Skull Cap" shown in Figure 11 has been added to the LDAR plot.

A large group of LDAR data points can be seen near the "Skull Cap", indicating a considerable number of electrical discharges at that location. Three of the field gradient vectors point to the skull cap, indicating a charge concentration to be located there. The highest field intensity (15.5 kv/m) is found next to, and pointing at, the "Skull Cap".

Only two LDAR data points are shown in the anvil region. By comparison of Figure 11 and Figure 12 one can see that three of the field vectors of Figure 11 point to a concentration of LDAR data points shown in Figure 12 to the northwest of the skull cap.

Note that the LDAR shows two electrical storms in progress one to the west, and one to the northwest. The radar precipitation return shown in Figure 13 makes this clear. The two storms are actually both part of a large precipitation pattern. In fact, the radar shows cores of activity ++ and x at both locations shown by the LDAR.

As before, the flight path is at the edge of the storm system, but this time is somewhat closer, as indicated by field readings reaching as high as 15 kv/m.

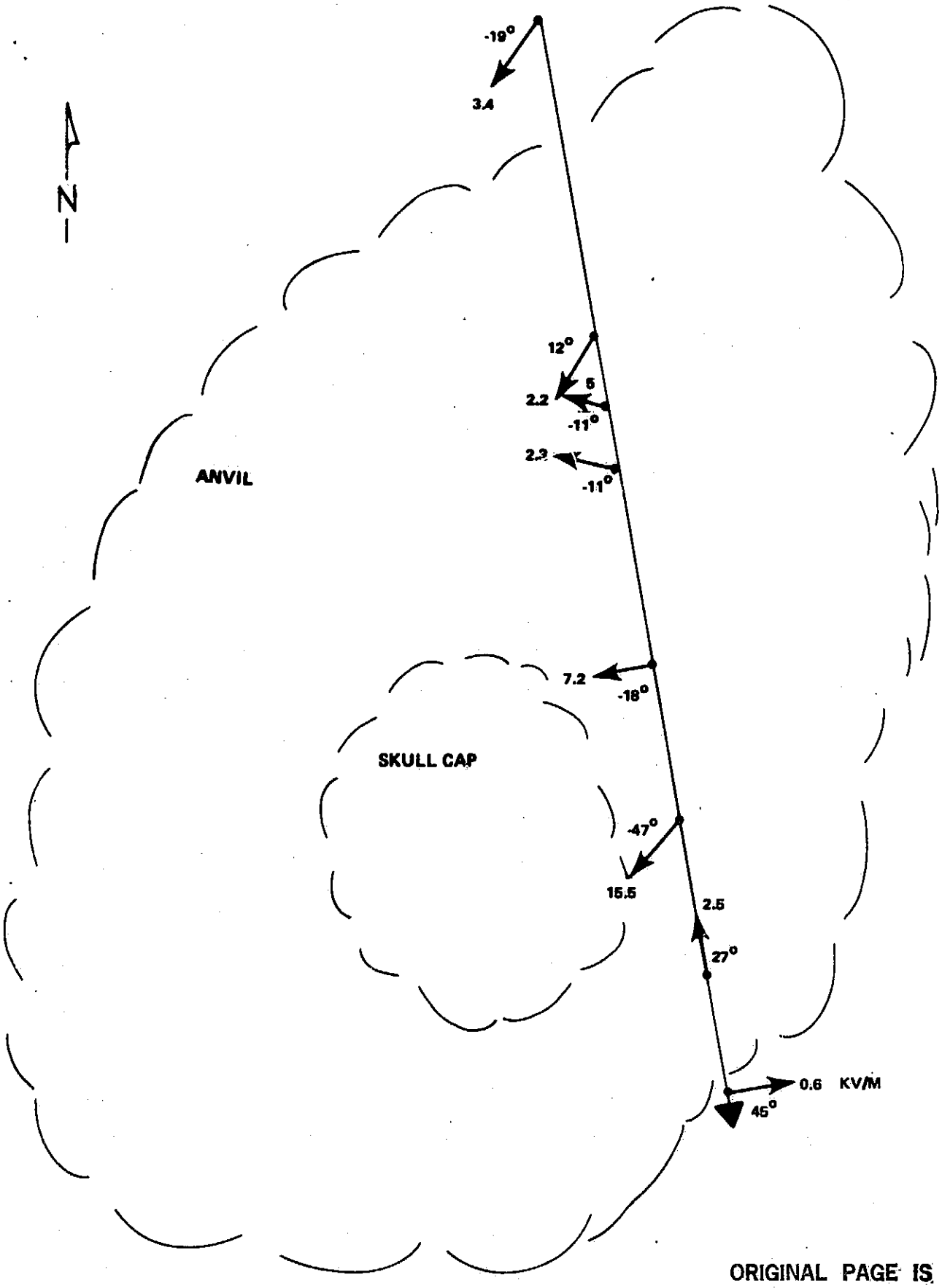

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FIGURE 11. PASS NO. 4, HEADING 170°,
ALTITUDE 39,200 FT.

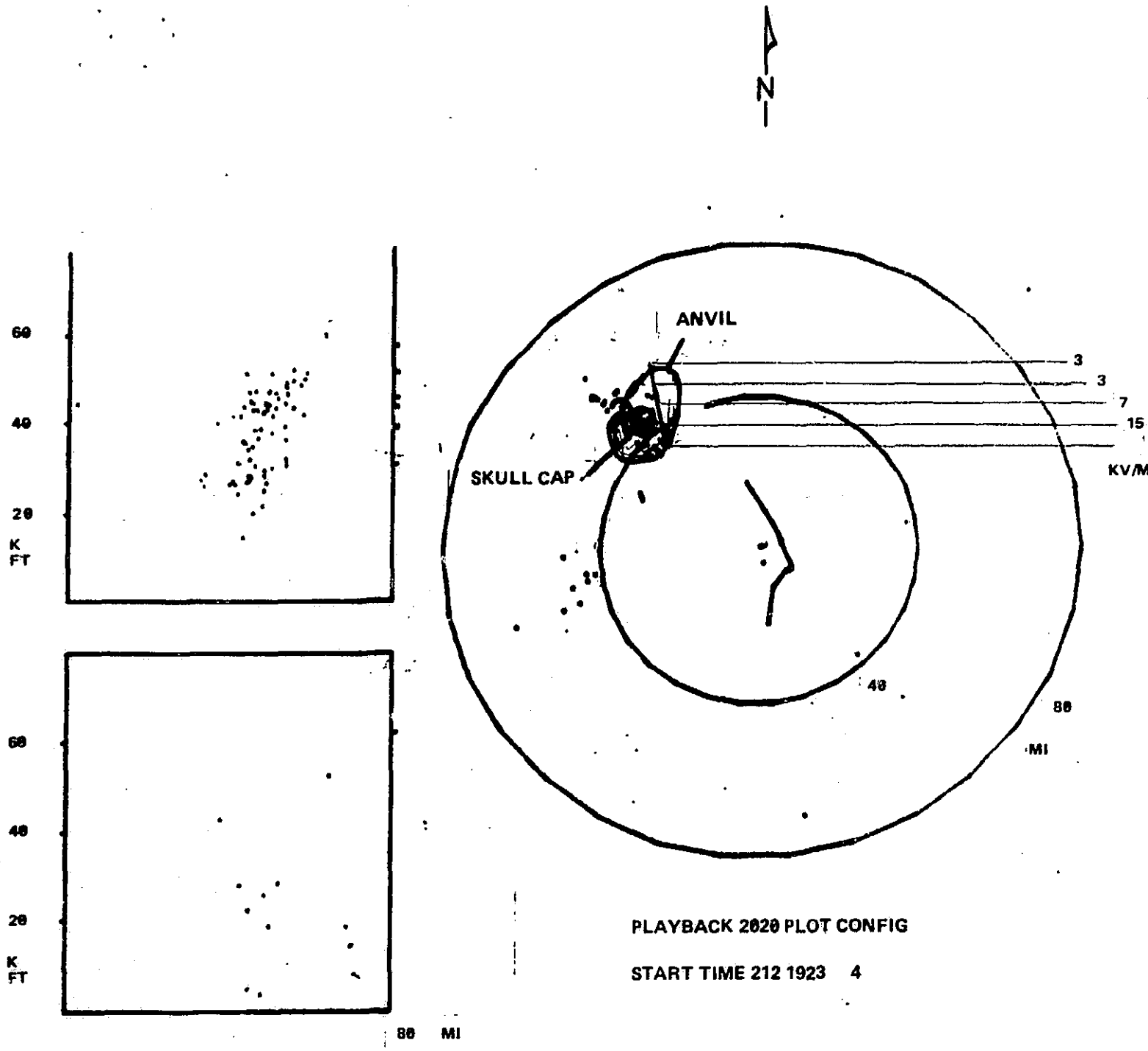

FIGURE 12. LDAR PLOT, PASS NO. 4

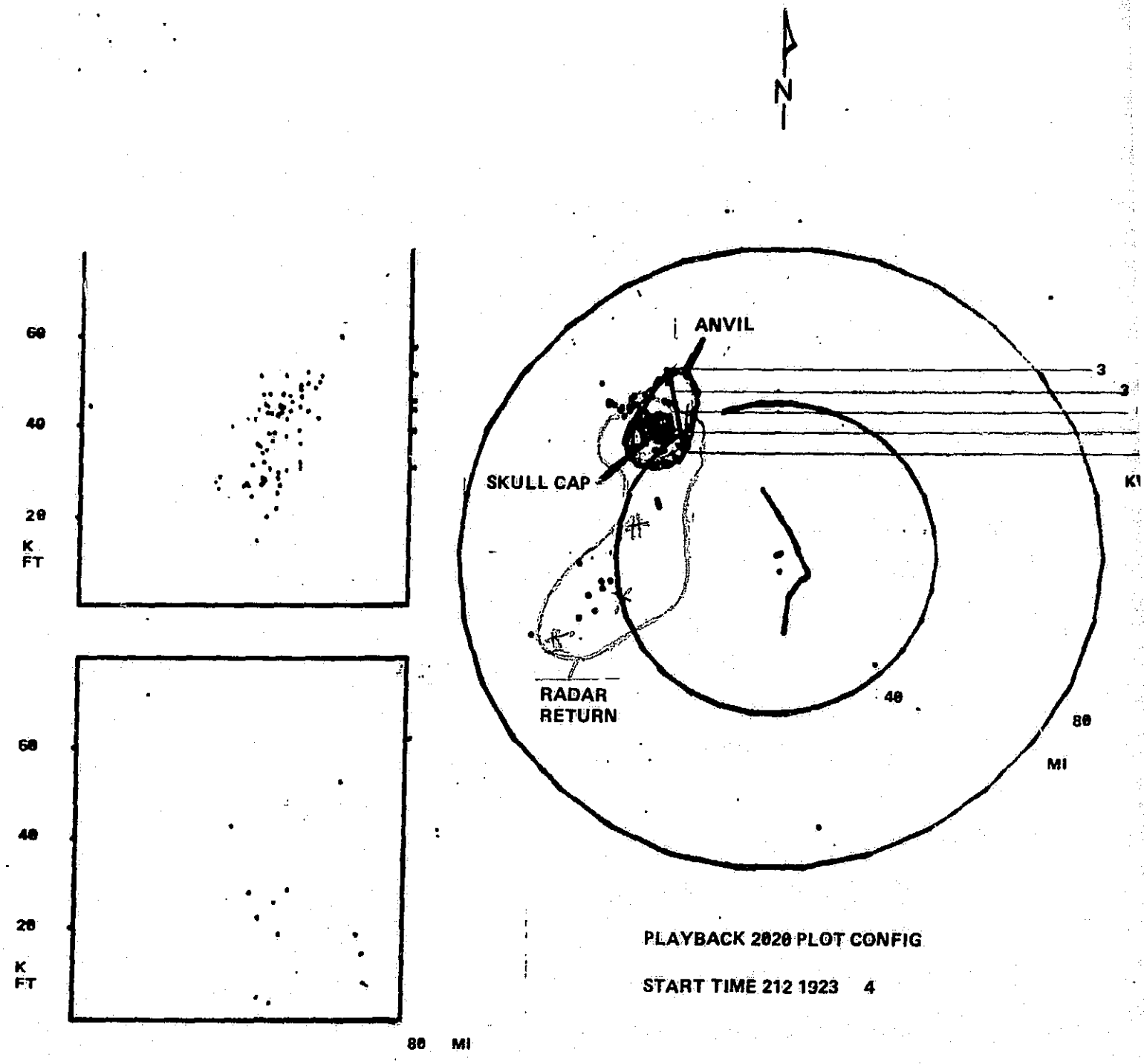

FIGURE 13. RADAR PRECIPITATION ECHO ADDED TO LDAR PLOT, PASS 4

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Pass No. 5

Pass No. 5 is shown in Figure 14, along with the measured values of the electric field in kv/m, declination in degrees, and a sketch of the surrounding clouds as seen from the airplane.

The corresponding LDAR plot, for the time period 1932-1937 GMT is shown in Figure 15. The position of the "Anvil" and the "New Cloud Building", shown in Figure 14, has been added to the LDAR plot.

Examination of the LDAR plot shows a number of LDAR data points in the neighborhood of the "New Cloud Building".

Field intensities in the neighborhood of the "New Cloud Building" reach high values (6.5 to 19 kv/m). No LDAR data points are shown in the anvil.

The second storm in the west is seen to have diminished in intensity.

The radar precipitation echo has been added in Figure 16. The location of the LDAR returns can be seen to correspond to the centers of activity ++ and x shown by the radar.

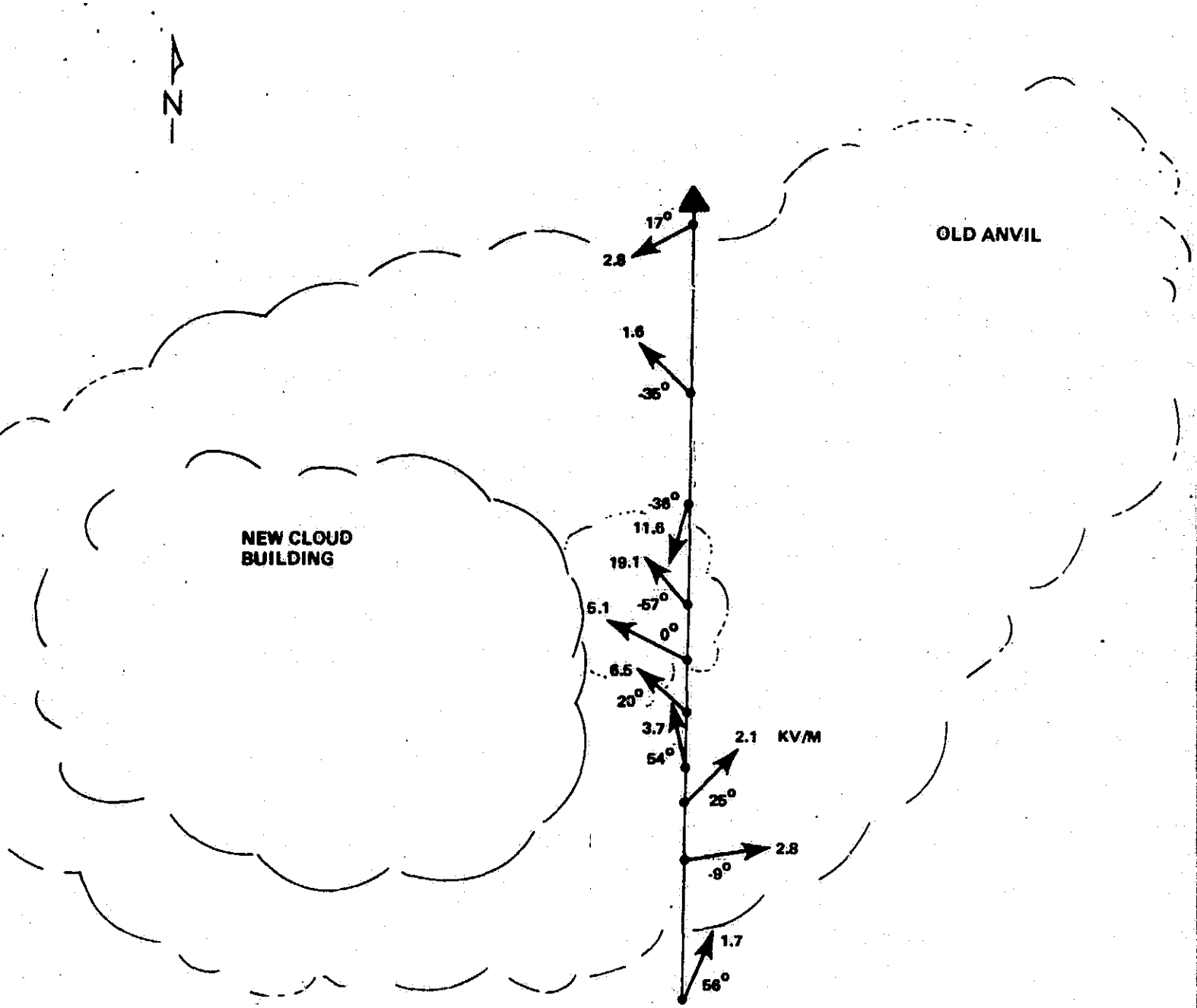

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FIGURE 14. PASS NO. 5, HEADING 0°, ALTITUDE 39,000 FT.

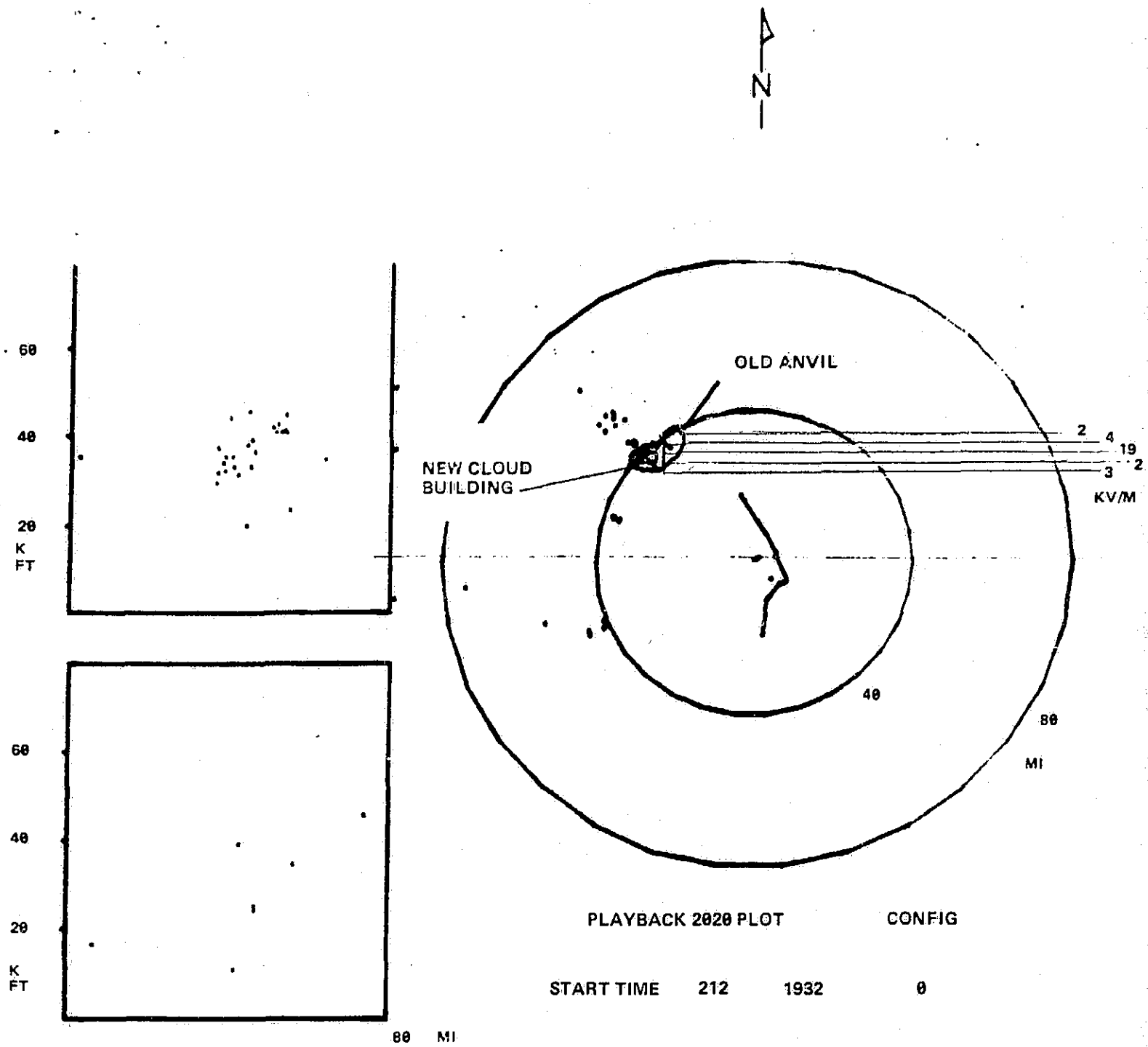

FIGURE 15. LDAR PLOT, PASS NO. 5

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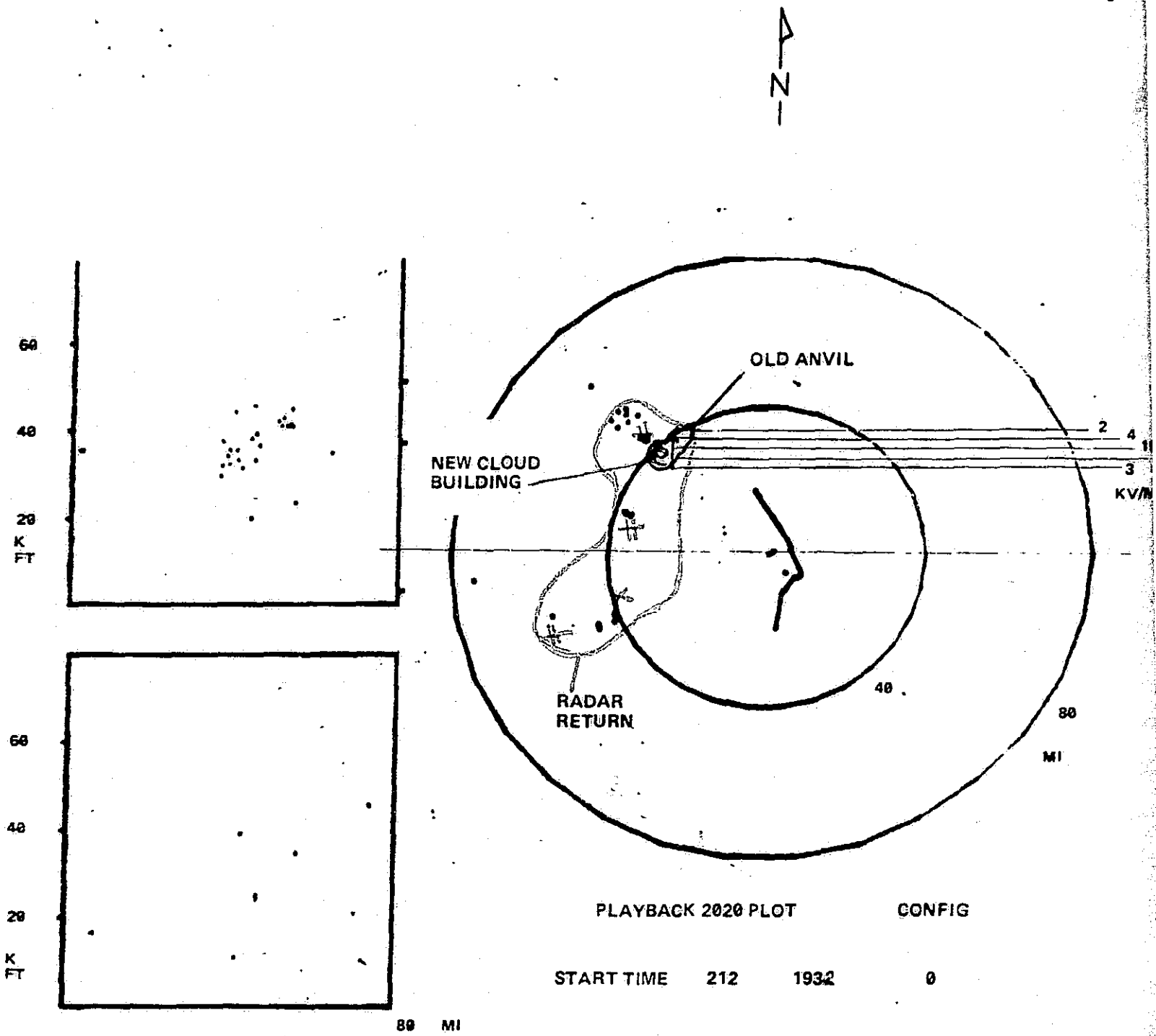

FIGURE 16. RADAR PRECIPITATION ECHO ADDED TO LDAR PLOT, PASS 5

Pass No. 6

Pass No. 6 is shown in Figure 17, along with the measured values of the electric field in kv/m, declination in degrees, and a sketch of the surrounding clouds as seen from the airplane.

The corresponding LDAR plot, for the time period 1937-1939 GMT, is shown in Figure 18. The position of the "Old Anvil" and the "New Cloud" as given in Figure 17 has been sketched on the LDAR plot.

No LDAR data points are visible either in the "New Cloud" or in the "Old Anvil".

The electrical activity in the west has diminished somewhat.

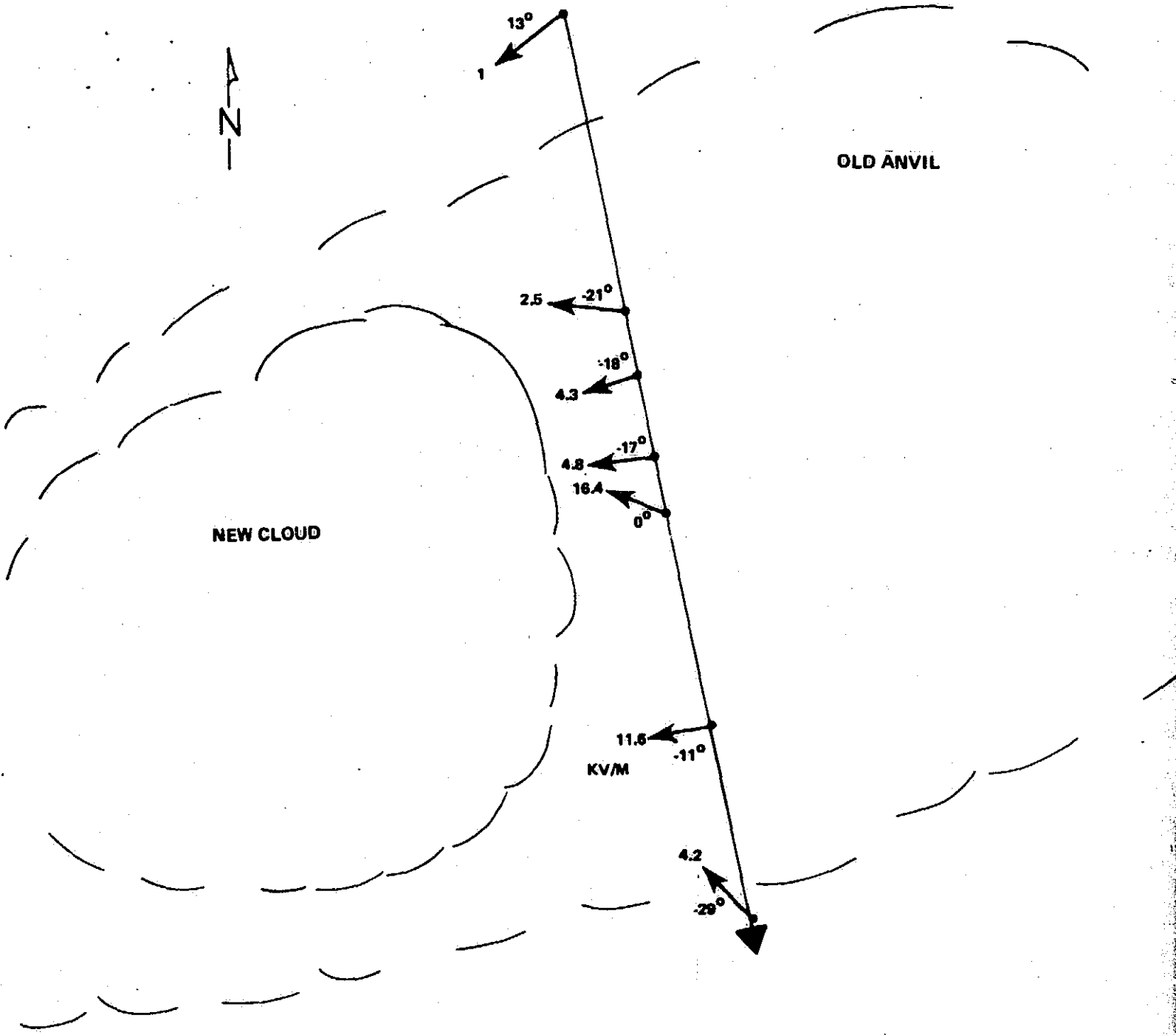

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FIGURE 17. PASS NO. 6, HEADING 168°, ALTITUDE 39,000 FT.

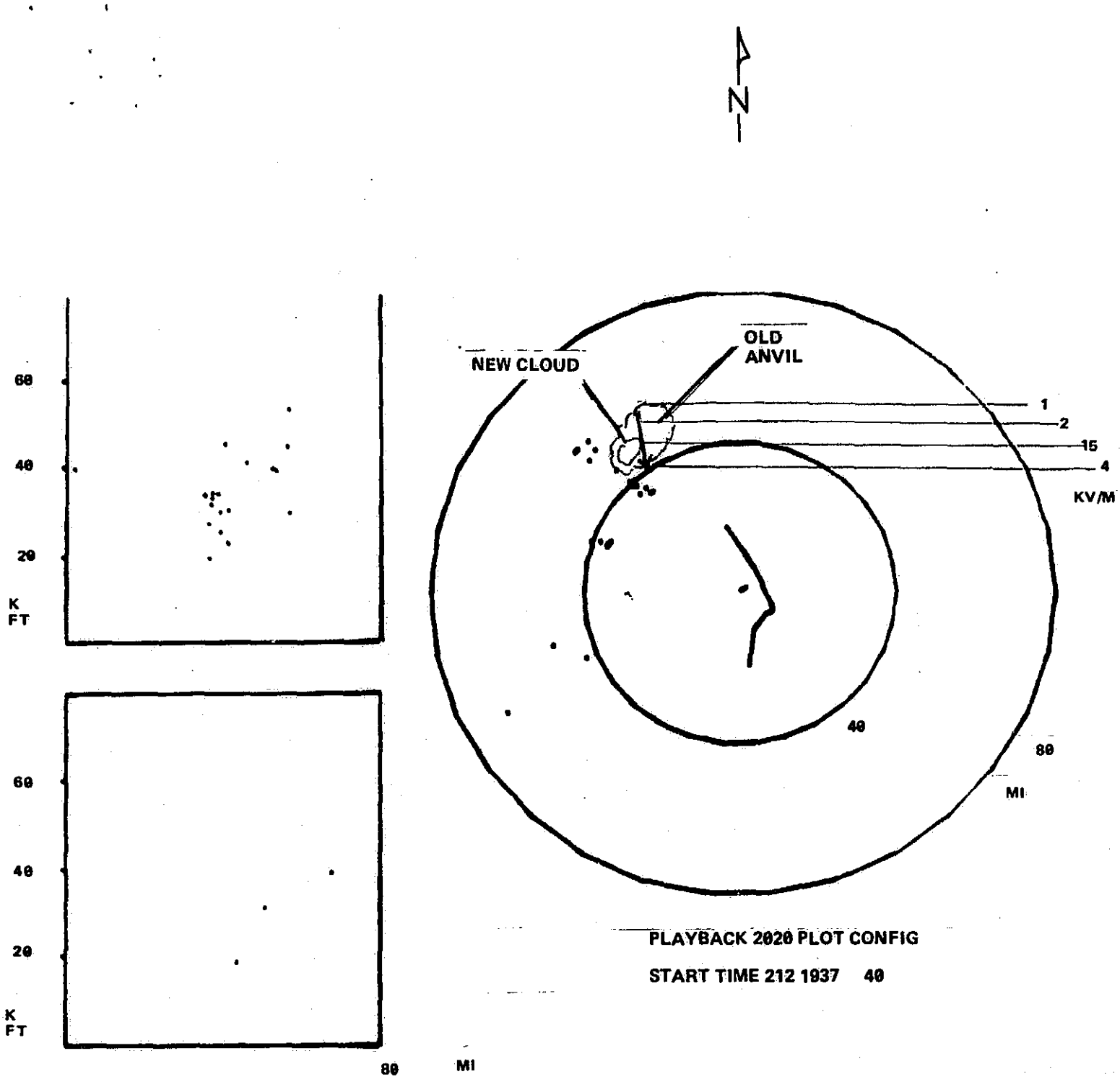

FIGURE 18. LDAR PLOT, PASS NO. 6

Pass No. 7

Pass No. 7 is shown in Figure 19,along with the measured values of the electric field in kv/m, declination in degrees, and a sketch of the surrounding clouds, as seen from the airplane.

The corresponding LDAR plot, for the time period 1943-1946 GMT, is shown in Figure 20. The position of the "Old Anvil" and the "New Cloud", as given in Figure 19 has been sketched on the LDAR plot.

A number of LDAR data points appear at the edge of the "New Cloud". Only a few LDAR data points appear within the anvil. The highest electric gradients, 63.6 to 65.3 kv/m, measured on any pass appear within the "New Cloud", as shown in Figure 19.

The electrical storm in the west has resumed activity, accordingly the LDAR plot shows two storms in progress.

The radar precipitation echo is shown superimposed on the LDAR plot in Figure 21. The LDAR response is seen to be in good agreement with the radar plot.

The airplane pass is seen to be much closer to the storm center than on previous passes. This is confirmed by highest (53 to 65.3 kv/m) levels of electrical intensity which were measured on this pass.

4. Discussion

The measured values of airborne electric field intensities for July 30, range between 0.5 and 65.3 kv/m. These values are in good agreement with published values of airborne electric field strength. For example, Kasemir,[5] reports 0.1 kv/m for cumulus clouds with tops up to 12,000 feet. Gunn[6] reports electric fields less than 1 kv/m for normal clouds without

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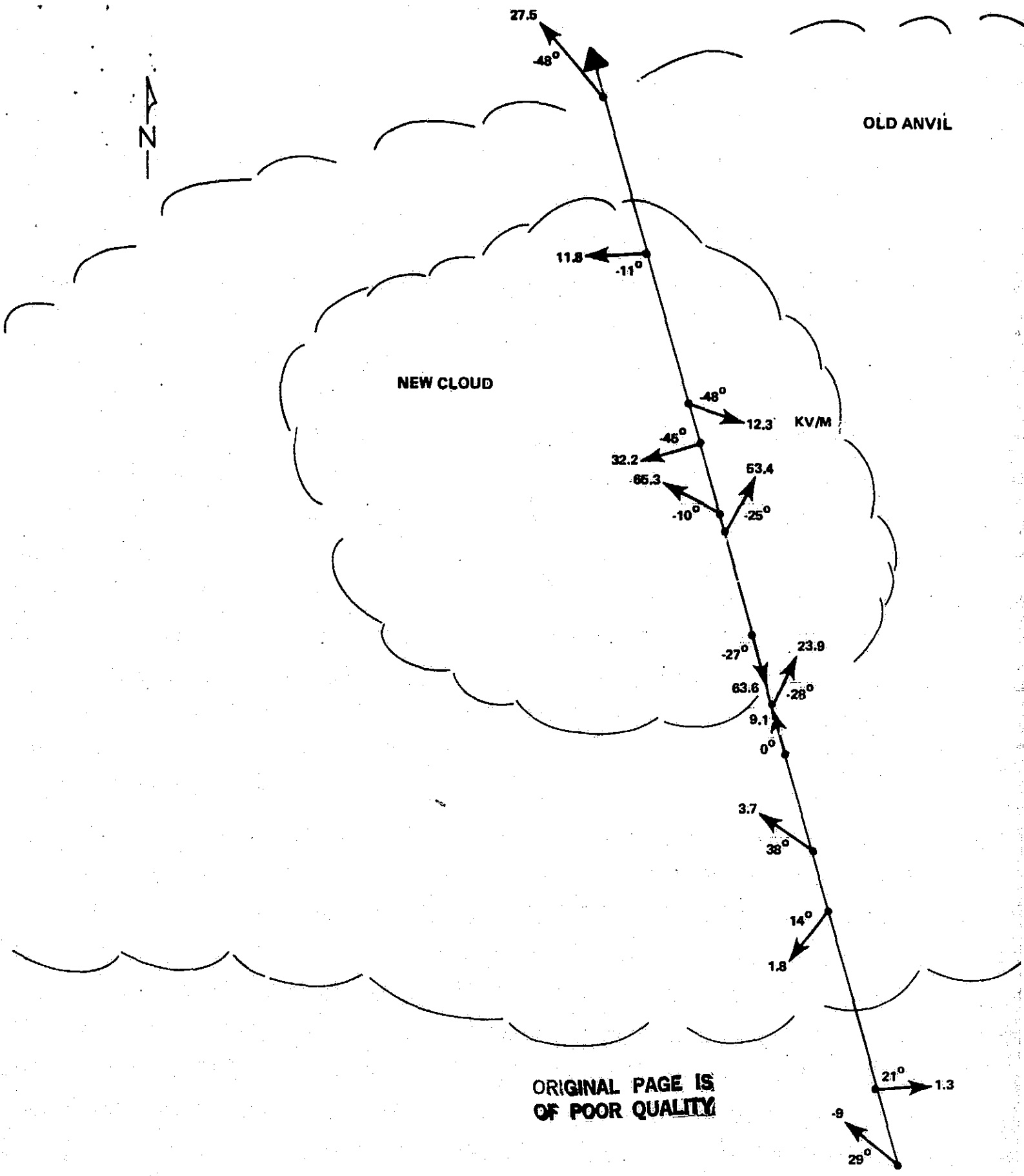

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FIGURE 19. PASS NO. 7, HEADING 345°, ALTITUDE 43,000 FT.

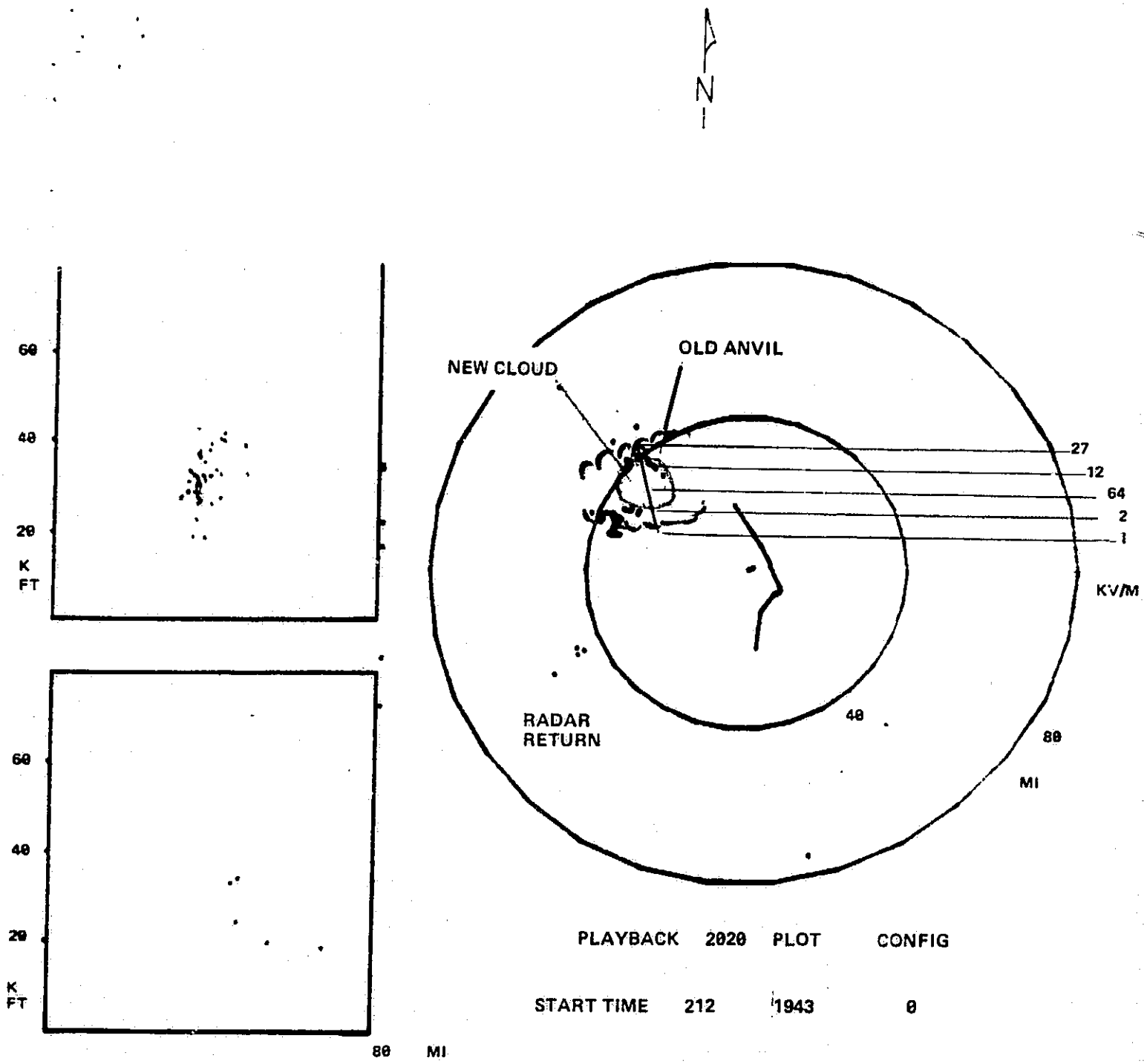

FIGURE 20. LDAR PLOT, PASS NO. 7

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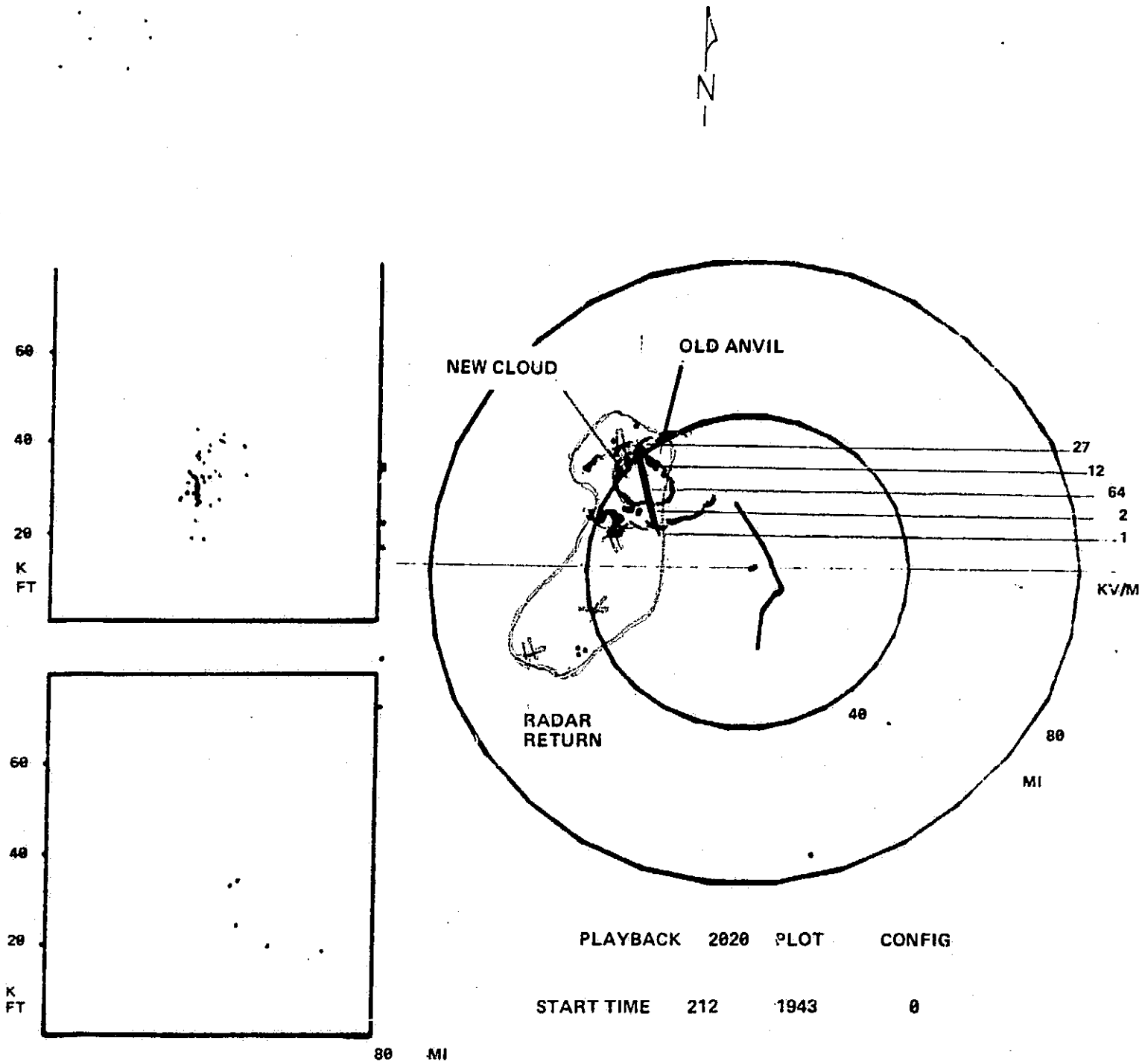

FIGURE 21. RADAR PRECIPITATION ECHO ADDED TO LDAR PLOT, PASS 7

precipitation. For clouds producing steady rain but not showing any appreciable convective activity, Gunn cites cloud electrical fields levels less than 4 kv/m. Fitzgerald,[7] reports 20 kv/m for the growing stages of cumulus congestus with an anvil-like upper portion when precipitation begins to fall out. Fitzgerald also reports 50 kv/m in clear air flights around thunderstorm masses. Gunn,[6] reports 130 kv/m as the average value for the interior of thunderstorms, with isolated values as high as 340 kv/m. Fitzgerald reports a high value of 390 kv/m,[8].

The highest value of field strength measured on July 30, does not exceed 65.3 kv/m . This is explained by the operational rules which specified that the airplane was not to fly through the core of the thundercloud, but around it, maintaining a safe distance.

The electric field intensity required to break down air at ground level is 3,000 kv/m. At the elevation of a thunderstorm cloud, this value decreases because of the reduced pressure, and is generally considered to be 2,000 kv/m.

The fact that lightning is observed in clouds where field intensities, the order of 200 kv/m are measured is usually explained by the concentration of the electric field that accompanies the distortion of water drops in high electric fields. In the presence of water drops, therefore, electric field intensities of as low as 200 kv/m are considered sufficient to initiate a lightning discharge.

Rockets can also distort, and thereby concentrate a relatively low ambient electrical field, to a level sufficient to trigger lightning. This is of particular concern to the Kennedy Space Center. As Kasemir,[9] has pointed out a rocket distorts the amient field producing a concentrated field at the tips, so that for a Saturn missile an ambient electric field of only

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20 kv/m is estimated as sufficient to trigger lightning.

Using the data given in Figures 4, 6, 10, 12, 15, 18, and 20, for each airborne electric field reading we can determine the horizontal distance to the nearest LDAR data point. The data are plotted in Figure 22, which presents the measured airborne electric field as a function of the horizontal distance to the nearest LDAR data point. All of the data points shown are measured, except for the electric field at the LDAR data point. The value of the field, here, has been estimated at 200 kv/m, which is generally considered as the minimum field intensity required to break down air at the level of a cloud, in the presence of water droplets. This estimated value seems to fit the data quite well.

The importance of Figure 22 is that it provides us with the ability to estimate the electric field in the vicinity of an LDAR data point. For example, Figure 22 indicates that the 20 kv/m level predicted by Kasemir as sufficient to trigger lightning for a missile of the Saturn type is found at 2 statute miles of an LDAR data point. If we desire a more conservative estimate, we can take the maximum distance at which a 20 kv/m is reached for any data point. This would indicate that an electric field of 20 kv/m could be reached at a distance of 5 statute miles from an LDAR data point.

Additional data, that will hopefully be gathered during the 1977 Thunderstorm II Project, should provide a more statistically valid data for the electric field-distance relation for LDAR data points. Most important is that the airborne electric field data be supplied with a more precise time and position data. Probably the prime reason for the large amount of scatter evident in the data points of Figure 22 is the limited precision of the time

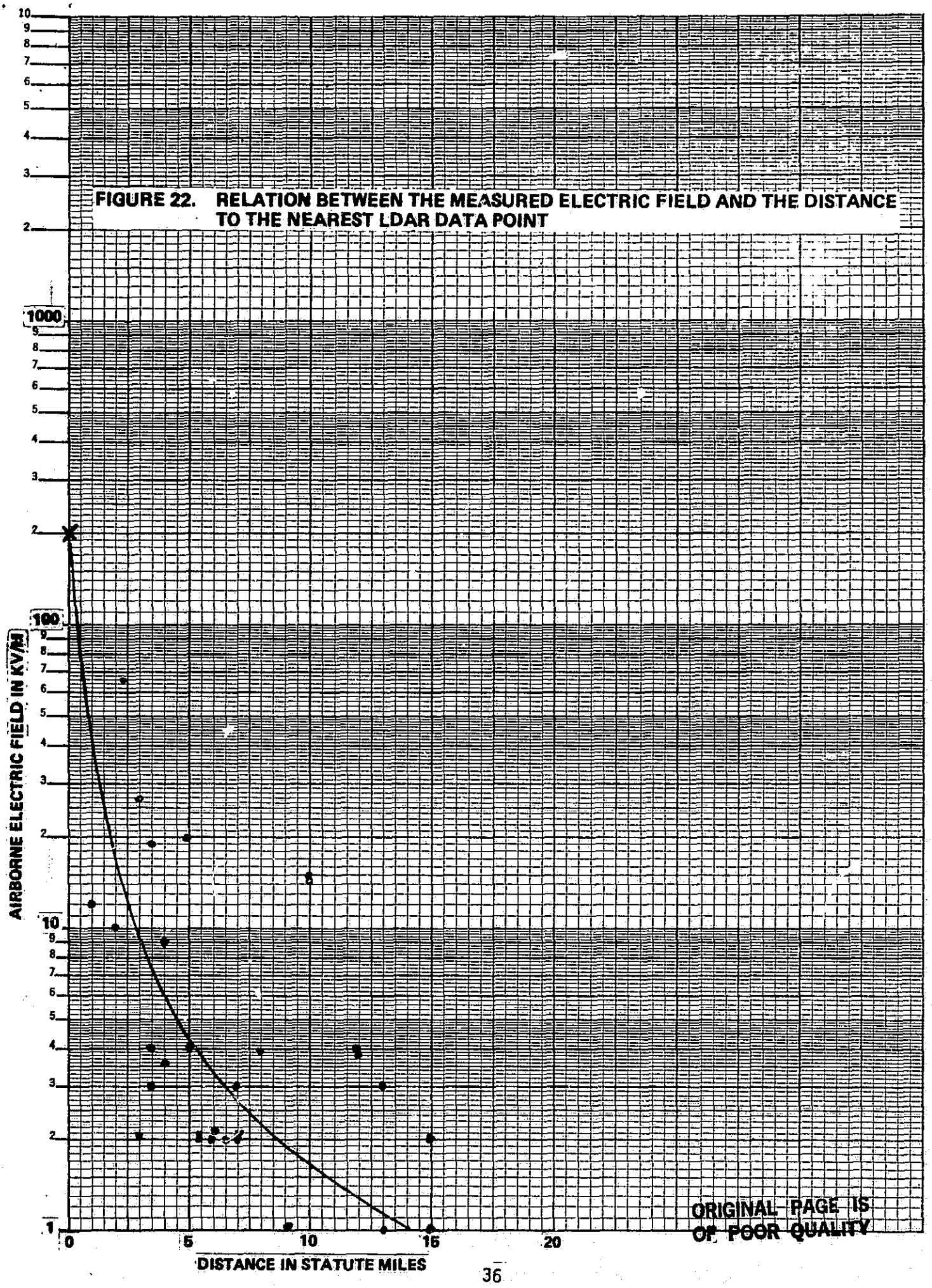

FIGURE 22. RELATION BETWEEN THE MEASURED ELECTRIC FIELD AND THE DISTANCE TO THE NEAREST LDAR DATA POINT

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data supplied for the airborne electric field readings used in this report. Time data was read from a wrist watch, and is likely no more precise than one second at best. For this reason it was not possible to match the LDAR data points in altitude. In Figure 22 we had to content ourselves with using the horizontal distance, rather than the more meaningful slant distances.

To utilize the capability of LDAR in the next joint experiment, airborne electric field intensity should be presented on a millisecond time scale and position data obtained by the use of a transponder and a Cape tracking radar.

III. CONCLUSIONS

1. Good agreement between airborne electric field and LDAR data was obtained for all seven of the seven passes of July 30, 1976, for which simultaneous data was available.

2. Sufficient data was obtained to permit drawing of a curve relating airborne electric field intensity vs the horizontal distance to the electrical discharges detected by LDAR.

3. Data from the July 30 test indicates that a field strength of 20 kv/m will be reached at a distance of 2 statute miles from an electrical discharge indicated by LDAR. Accordingly LDAR can be used to map out areas in the sky which must be avoided if triggered lightning is to be avoided.

IV. RECOMMENDATIONS

1. It is recommended that joint LDAR airborne electric field strength data be collected during 1977 Thunderstorm II Project, and it is suggested that aircraft flights be coordinated with LDAR, so as to take advantage of LDAR's ability to map out the electrically active areas in the sky.

2. It is recommended that more of the airborne field intensity data be taken within the 40 mile range of LDAR, and that some data be taken within the 10 mile high precision accuracy range of LDAR.

3. It is important that airborne field intensity data be provided with more accurate timing and position data. In order to make better use of the capability of LDAR, it is recommended that millisecond time data be provided together with position determined by a transponder and a Cape tracking radar.

V. REFERENCES

1. Johnson Space Center, "JSC Thunderstorm Experiment, July-August 1975" in publication, Johnson Space Center, Texas.

2. Lennon, C. L., "LDAR - A Lightning Detection and Ranging System", Minutes of the Frequency Management Group, Range Commanders Council, 7-9 October, 1975, Washington, D.C., Published by the Secretariat, Range Commanders Council, White Sands Missile Range, New Mexico, 99002, Pages R1-R25.

3. Lennon, C.L., "The Performance of a Real-Time, Time-of-Arrival Lightning Location System (LDAR)", Presented at the 1976 Fall Annual Meeting, American Geophysical Union, December 6-10. Abstract appears in EOS, Transactions, American Geophysical Union, Vol. 57, No. 12, December 1976. Full paper available from NASA, IN-TEL-32, Kennedy Space Center, Florida, 32899.

4. Poehler, H.A., "An Accuracy Analysis of the LDAR System" Test Report No. 7146, January 1977, Federal Electric Corp., RF Systems Branch, Kennedy Space Center, Florida, 32899.

5. Kasemir, H., "Field Measurements Inside Cumulus Clouds with Tops Above 12,000 Feet", Note 2, Contract # CC-47732, Kennedy Space Center, Florida, 1976.

6. Gunn, "Electric Field Intensity Inside of Natural Clouds", Journal of Applied Physics, Vo. 19, May 1948, pp. 481-484.

7. Fitzgerald, D.R., in Handbook of Geophysics and Space Environment, Chapt. 8, Air Force Cambridge Research Labs, Cambridge, Mass., 1965, pp. 8-8 to 8-10.

8. Fitzgerald, D.R., "Probable Aircraft "Triggering" of Lightning in Certain Thunderstorms", US Dept. of Commerce, Monthly Weather Review, Vol. 95, No. 12, Dec. 1967, pp. 835-842.

9. Kasemir, H.W., "Lightning Hazard to Rockets During Launch, I" ESSA Technical Report, ERL 143-APCL 11 Atmospheric Physics and Chemistry Lab., Boulder, Colorado, Dec. 1969.

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15. Abstract For a summer thunderstorm, for which simultaneous, airborne electric field measurements and Lightning Detection and Ranging (LDAR)System data was available, measurements were coordinated to present a picture of the electric field intensity near cloud electrical discharges detected by the LDAR System. Radar precipitation echoes from NOAA's 10 cm weather radar and measured airborne electric field intensities have been superimposed on LDAR plots to present a coordinated data picture of thunderstorm activity.

16. Key Words Lightning, Atmospheric Electricity, Thunderstorms, Measurements, Precipitation, Radar

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