A UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

NOAA Technical Memorandum NWS CR-45

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

THE RELATIONSHIP OF SOME CIRRUS FORMATIONS TO SEVERE LOCAL STORMS

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CENTRAL REGION
Kansas City, Mo.

JULY 1971

NOAA TECHNICAL MEMORANDUM *

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William E. Williams
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1. INTRODUCTION

An Operational Experiment using mainly the Applications Technology Satellite III (ATS III) began in the spring of 1970 at the National Severe Storms Forecast Center (NSSFC). The primary objective of this continuing test is to develop applications of real time satellite data to the forecasting of severe local storms. An example of such use is presented below.

The ATS III is in a quasi-geostationary orbit about the Earth. In this orbit the satellite appears stationary above any given geographic location. The true geostationary orbit lies in the equatorial plane 22,300 miles above the Earth. The ATS III approximates this very closely with a variation of only about a degree and a half departure both north and south of the equator in a 24-hour period. This oscillation is increasing slowly with time. On 12 March 1971, the date of concern here, the geodetic satellite sub-point was very close to 67 degrees west longitude.

Full disk Earth pictures may be obtained at intervals of about 26 minutes. A very valuable feature of the system is that the scanning sequence may be stopped upon command from the Command and Data Acquisition Station and a new sequence of scans begun sooner than usual. This allows more frequent sensing of the northern part of the hemisphere. This is particularly useful in the study of short-lived cloud features. The resolution of the sensor system is about 2 miles directly beneath the satellite and degrades to about 4 miles over the contiguous portion of the United States.

The picture data from the satellite are received in NSSFC in real time and enlarged photographs of the United States portion are made. Perhaps the most valuable photographic product of the processing system is the animated movie loop. This is made by photographing each negative in sequence, resulting in a length of film that, when the ends are spliced together, can be shown repeatedly on a movie projector, hence the term movie loop. When viewed at an appropriate speed, the pictures appear animated and motions of individual elements or cloud systems can be determined, which without the loop would be almost impossible to see.

2. HYPOTHESIS

Case studies of data collected in the 1970 tornado season led to the discovery of a possible relationship between some distinctive cirrus formations and the later occurrence of severe local storms. Based on these studies, a hypothesis was formed that these cirrus were associated with a trough aloft which, as it moved over a suitable unstable airmass, acted as a triggering mechanism to initiate the growth of severe thunderstorms. These suitable airmasses are characterized as having very moist air at low levels with an inversion near the 850 mb level and dry air above. A "dry line" is its usual western boundary. Such an airmass is conditionally very unstable and if by some method the inversion is quickly "removed", severe local storms are likely to develop.

The following presents as a representative example, the occurrences of 12 March 1971.

3. METEOROLOGICAL CONDITIONS

Figure 1 depicts the 1400Z location of the surface low center and dry line that moved across Texas during the day to the 0000Z position shown. Also indicated at 0000Z are the axis of the maximum low-level wind which was 20-25 knots, the low-level maximum moisture axis, and the -4 and -6 isolines of lifted index. Dewpoints east of the dry line were mostly in the 60s while west they were mainly less than 30. Lifted index values west of the dry line were +4 or higher. The wind, moisture, and instability axes shifted little during the day as the surface temperatures rose into the 80s and low 90s.

4. CIRRUS FORMATIONS

Figure 2 gives the positions of the leading edge of a line of cirrus on 12 March 1971, as determined from available ATS III cloud photographs (at 26-minute intervals from 1400Z to 2008Z) and extrapolated, with use of upper-level charts, thereafter. If it were not for the time-lapse movie loop, the presence and organized movement of these lines would probably not have been as clearly noticed, as the line is rather wispy in the pictures and is easily lost in individual pictures especially when it is near other clouds.

Figure 3 (the second picture of the day) shows the tenuous nature of the line (delineated by arrows) at a time before any convective activity was associated with it. Figure 4 shows the line a bit after the first radar echo was observed. Note the long line of convective activity west of the cirrus line. Figure 5 shows the line on the last photograph of the day. The pronounced convective activity shows up as a bright area just west of the line. Figure 6 is the NOAA I infrared picture at the same time as Figure 5. In infrared pictures brightness is inversely proportional to temperature, hence directly related to height. This photograph shows that the line is nearly as bright as the mass of convective tops just west, and therefore at a temperature not much warmer than that of the convective tops and thus in the cirrus level.

5. INTERRELATIONSHIPS

Figure 7 shows the positions of the cirrus line, the radar echoes taken from the RADU charts, the low center and the dry line, from 1400Z to 0000Z.

At 1400Z the cirrus line was considerably west of the dry line, and there was no convective activity near the dry line or cirrus line (see Fig. 3).

The cirrus line moved at 30 knots over the next two hours and overtook the dry line near Abilene, Texas at about 1600Z. The line depicted on the figures has termination points corresponding to the extremities of the visible cirrus on the photographs, even though the cause of the cloud line could extend farther in either direction, but perhaps with diminished strength. Near 1800Z the RADU chart displayed a small area of echoes (the first reported) near the cross-over, as shown. The ATS III picture at 1814Z (Figure 4) indicated considerable squall line development along the dry line from north Texas southward to near the intersection. In this figure it can be clearly seen that an initial line of cumulus had formed from the intersection of the dry line (convective cloud line) and cirrus line northward to connect with the squall line. This delay between the cirrus line crossing the dry line and the formation of radar echoes would be expected if the cirrus line was acting as a triggering mechanism to generate the squall line. The response time to the new conditions would probably be well correlated with the initial instability and the strength of the upper-air trough.

In the remaining charts, the squall line continues to develop both to the north and to the south. The southern tip extends to about 30°N before the decrease in instability and other parameters terminate it. To the north the instability field favors widespread thunderstorm development in addition to the squall line. There was large hail starting near 2100Z with the part of the squall line associated directly with the visible cirrus, and tornadoes occurred farther north, starting a bit later.

It should be noted in these figures that the cirrus acts as a trigger but continues moving eastward faster than the generated squall line. This is to be expected, since the cirrus line is moving with winds at around the 400 mb level, while the squall line moves more with a 700 mb wind.

6. A POSSIBLE CAUSE

Figures 8 and 9 show the 400 mb chart at roughly the beginning and end of the cirrus line as seen on the satellite pictures. Taking the cirrus line positions from Figure 2 and extrapolating to the times of the 400 mb charts suggests that the cirrus line was close to the position of a small 400 mb trough line, although the conventional upper-air data do not allow as much precision in the position of the trough line as can be determined with the cirrus line. While the height of the cirrus cloud line is known only roughly, its movement fits these 400 mb winds fairly well, while the 200 mb winds were twice as fast as the line movement, but there was a 300 mb and a 200 mb trough directly above the 400 mb trough. At 500 mb there was also a trough on the hand-analyzed facsimile chart, and it appeared to be directly below the 400 mb trough--no tilt of the trough with height from 500 mb to 200 mb. There was also a clear vorticity maximum on the objectively analyzed 500 mb vorticity chart. The wind speeds at 500 mb were 30-40 knots, and thus in the proper range for the movement of the cloud line.* The temperature at 500 mb was about -30°C, which is cold enough for cirrus, so the cloud line could have been almost down to 500 mb. At 300 mb the winds were somewhat faster than at 400 mb.

From this, we can say that the formation and movement of the squall line was probably associated with movement of a synoptic scale trough aloft at the 500 to 200 mb level. However, the more precise timing of the formation of the squall line can come from following the cloud line in the satellite pictures than from the trough on the constant pressure charts. The search

* Don't believe wind speed need be the same as trough speed in a case like this. [illegible]

for such distinctive cirrus formations has become a part of the diagnostic procedure in the NSSFC.

7. OTHER CASES

Six other cases of these distinctive (mostly wispy, relatively short, and roughly perpendicular to upper flow) cirrus lines have been noticed in the past year and a half. However, data are mostly available only about six hours a day, five days a week, and primarily in the warm part of the year. Also, such lines would probably not be noticed in cloudy areas, and most attention has been given to the central U. S. But all six lines noticed did initiate severe weather following the pattern described above. They occurred in the months of February, April, May, June, and July. From these it appears that the line is probably at a pressure of 500-400 mb in the cold season, but close to 200 mb in the warm season. In each case a squall line was initiated as the cirrus line crossed the surface dry line. However, it is only in the cold season that a clear ? upper level synoptic-scale trough is closely associated with the cirrus line. In the warm months, the line moved faster than the nearest synoptic-scale trough, and the presence of a meso-scale trough in the wind or height field was difficult to ascertain. It thus appears that the cirrus line located from the satellite pictures has maximum value in the warm season, but that better timing of the situation can come from the information in any season.

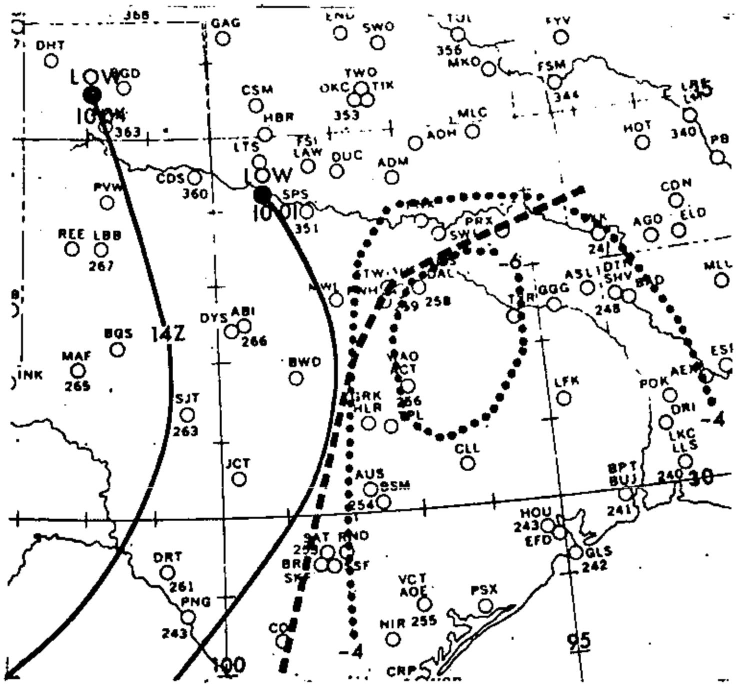

FIGURE 1

Surface low and dry line positions for 1400Z 3-12-71 and 0000Z 3-13-71. The dashed line indicates the low-level maximum moisture axis and also the axis of the maximum low-level winds for 0000Z. Isolines for 0000Z lifted index values of -4 and -6 are dotted.

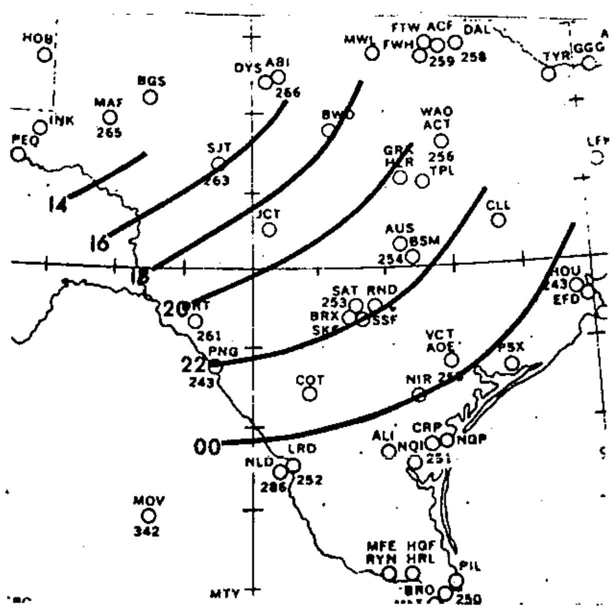

FIGURE 2

Successive positions of the leading edge of the cirrus line (Z time).

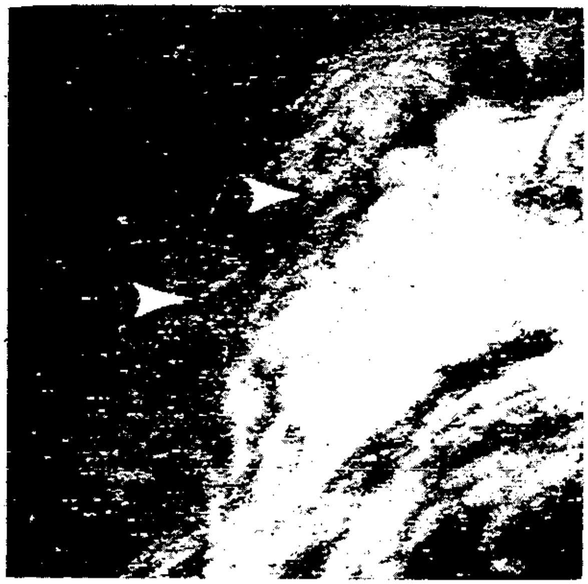

FIGURE 3

NSSFC ATS III #2 1427Z 3-12-71.

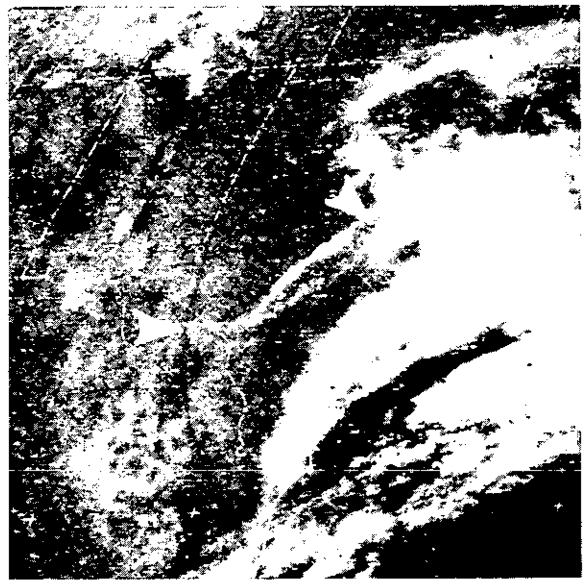

FIGURE 4

NSSFC ATS III #10 1814Z 3-12-71

FIGURE 5

NSSFC ATS III #15 2008Z 3-12-71.

FIGURE 6

NOAA I Infrared, Pass number 1145
2008Z 3-12-71.

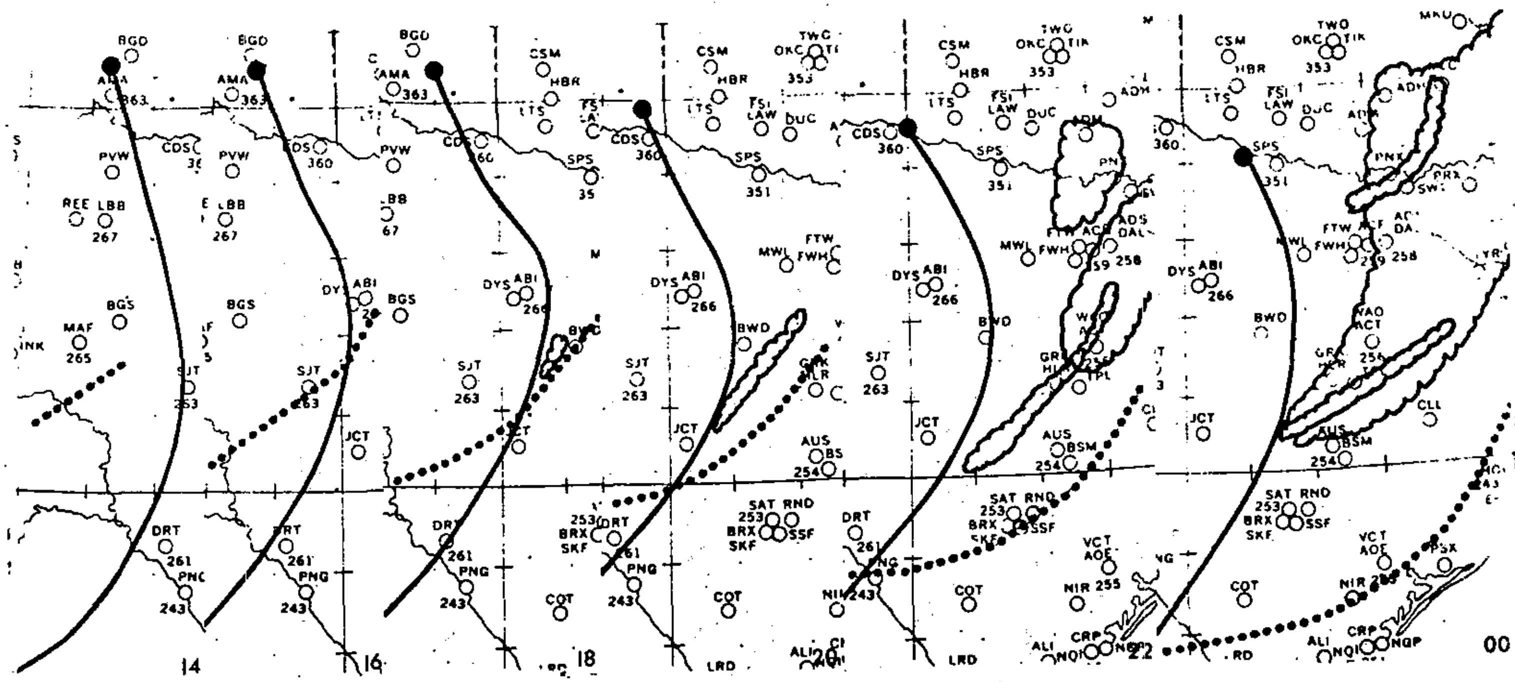

FIGURE 7

Successive plots, GMT, of the line of cirrus (dotted), RADU reports (scalloped) low center and dry line.

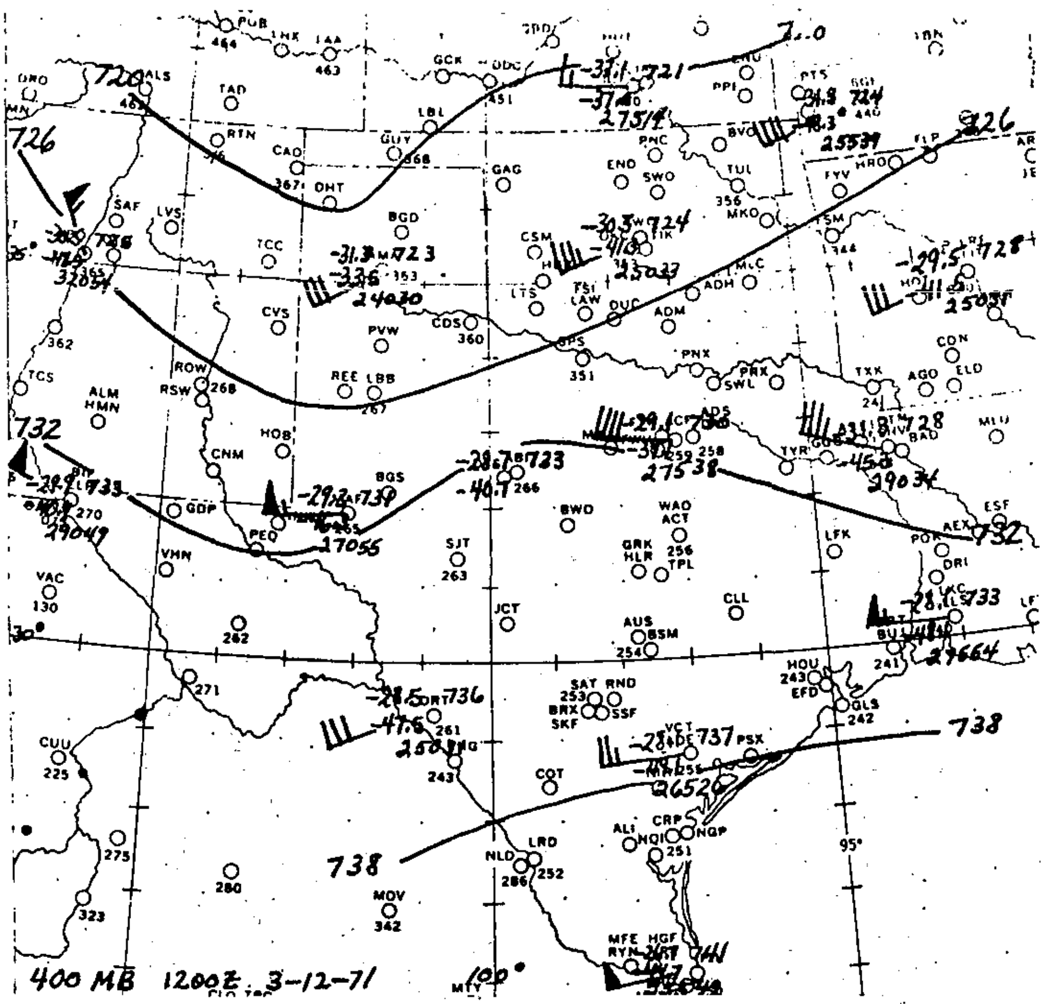

FIGURE 8

400 mb Chart 1200Z 3-12-71

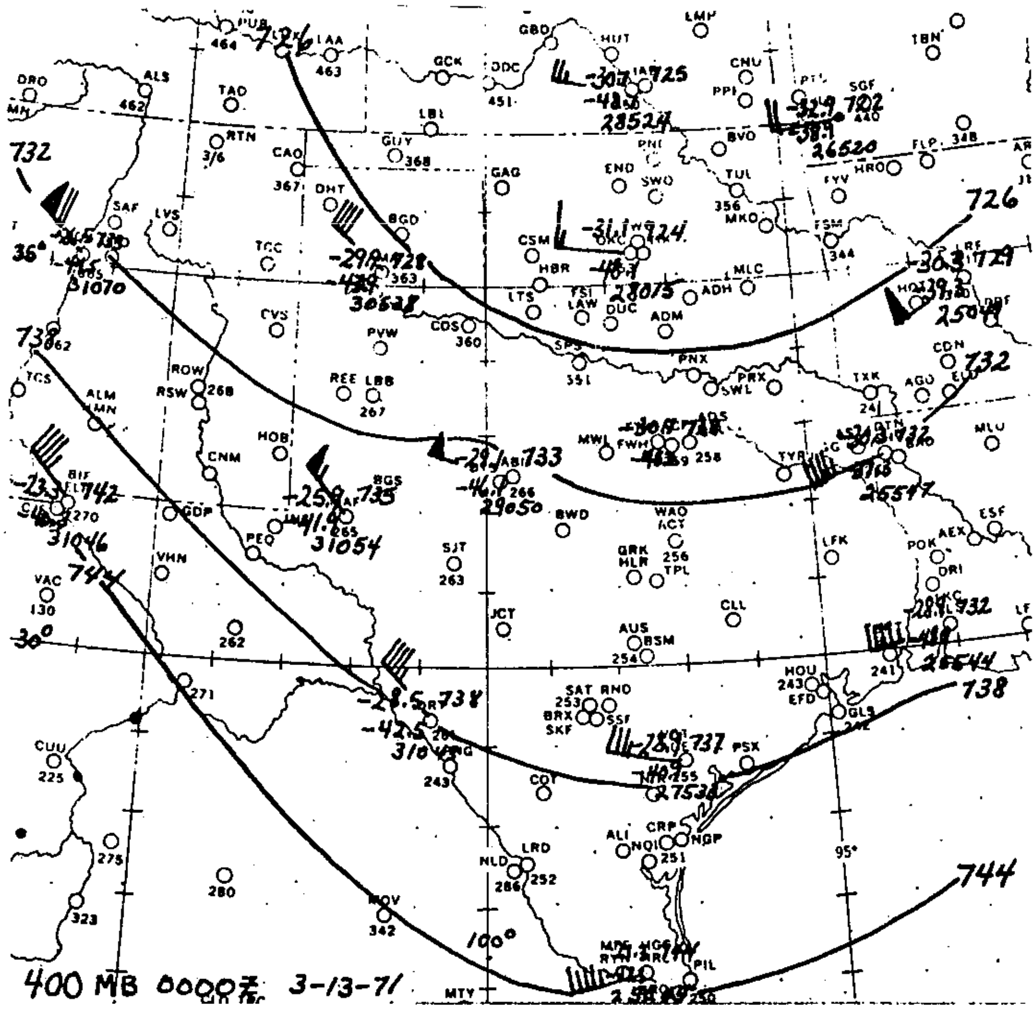

FIGURE 9

400 mb Chart 0000Z 3-13-71

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