

ERA24FA217

AIR TRAFFIC CONTROL

Group Chairman's Factual Report - Attachment 7

FAA AJW-1435 Report

April 16, 2026

Report on the Nashville ASR-9 Concerning the May 15, 2024 Tragedy

Background

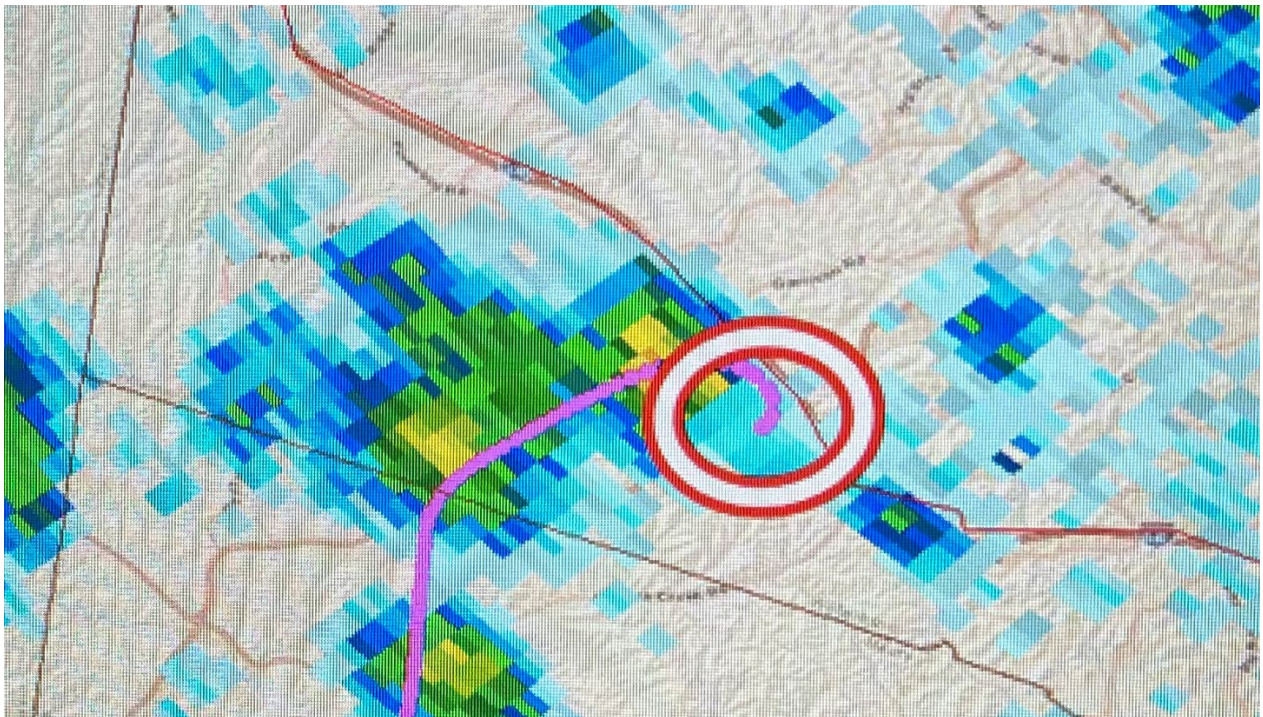
At approximately 1702Z (12:02 p.m. local time) on May 15, 2024, a 1966 Beechcraft Bonanza crashed near Franklin, TN resulting in three fatalities.

Reports indicate that the aircraft broke up in mid-air with the wreckage scattered near the intersection of Bending Chestnut Road and Davis Hollow Road.

This is very near the intersection of I-840 and Natchez Trace Parkway which is approximately 27.1 nautical miles (nmi) and 229.4 degrees from the Nashville (BNA) ASR-9.

The following image provided by the National Transportation Safety Board (NTSB) shows the track of the aircraft superimposed on an image of the weather from about the same time. The sources for both data are unknown.

Composite image from NTSB:



The image shows the aircraft passing through a single, orange-colored weather cell and making a near-180-degree right-hand turn. According to the FAA's Event Response Team (ERT), the NTSB indicated that

this orange-colored cell represents level 4 weather. Emails with preliminary information from the ERT appear to indicate that this weather cell was directly or indirectly the cause of the crash. This preliminary information also indicates that this weather cell was not displayed on the Standard Terminal Automation Replacement System (STARS).

What did the ASR-9 see?

STARS displays an advisory six-level-weather product produced by the Airport Surveillance Radar model 9 (ASR-9) radar. A separate display provides the truer weather picture as output by the Integrated Terminal Weather System (ITWS).

The ASR-9 has a scan rate of 4.62 seconds. It takes the radar six scans to create a complete weather map which is then transmitted to STARS at the Terminal Radar Approach Control (TRACON) facility. Thus, the controllers see an updated weather representation once every 27.7 seconds on their scopes. The ITWS Vertically Integrated Liquid (VIL) weather map updates once every 2.5 minutes.

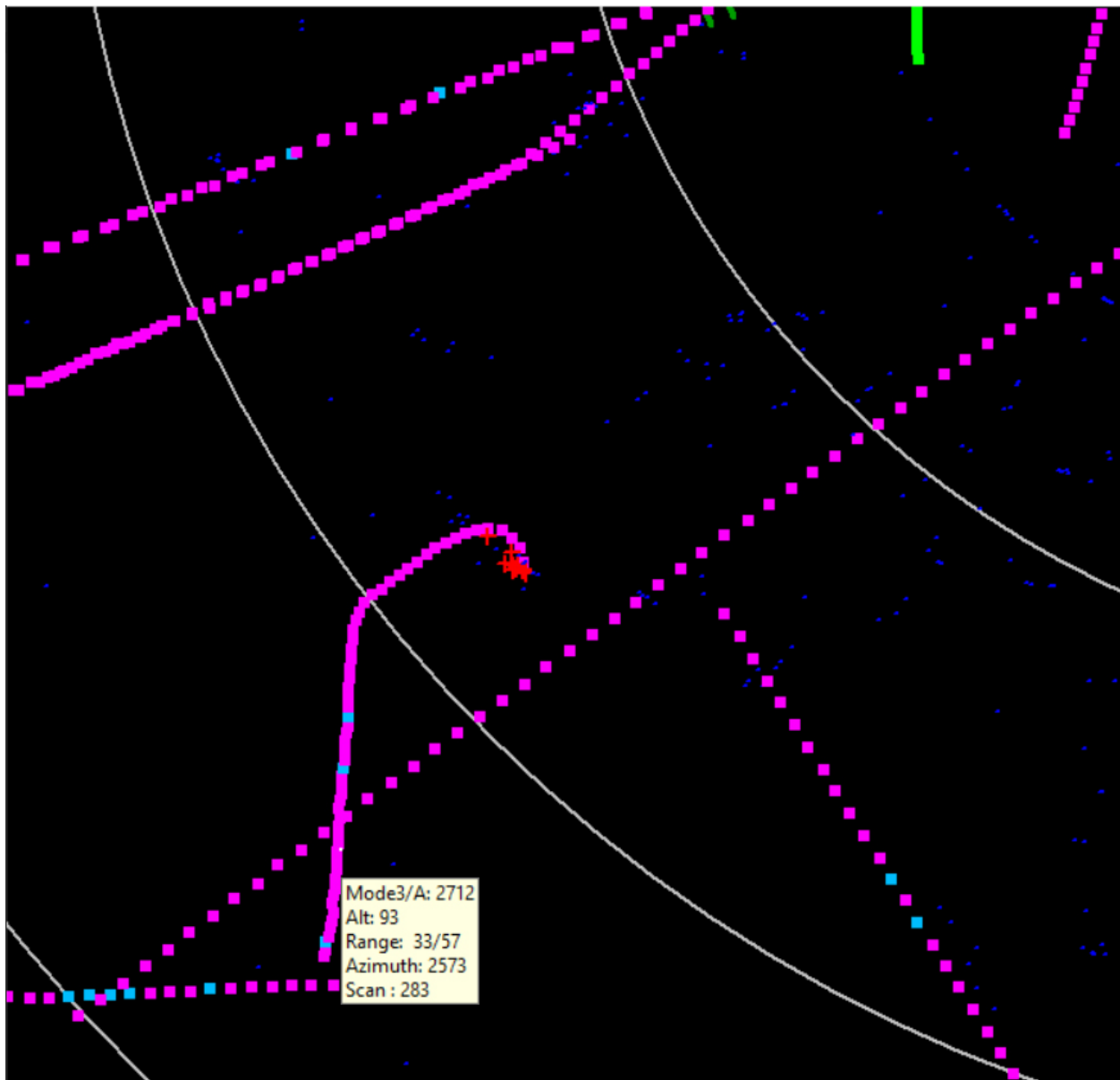
Radar data was collected from the ASR-9 radar site for analysis. The data file of interest recorded by the Remote Monitoring Subsystem (RMS) Computer-Radar Interface Box (CRIB) is "rec-BNA_-240515-1636.cdr." The following image shows the last 80 scans (six minutes) of the aircraft's flight (mode 3/A code 2712). This image shows the history of several aircraft tracks but not the weather history.

Legend:

Purple square	Radar-reinforced Mode-S target report
Light blue square	Beacon-only Mode-S target report
Green square	Radar-reinforced ATCRBS target report
Yellow square	Beacon-only ATCRBS target report
Blue dot	Uncorrelated radar-only target report
Red plus sign	Correlated radar-only target report
Green dots	Level 1 weather cells

The range rings shown are at 20, 30 and 40 nautical miles distance from the radar site. Altitude values are shown in hundreds of feet.

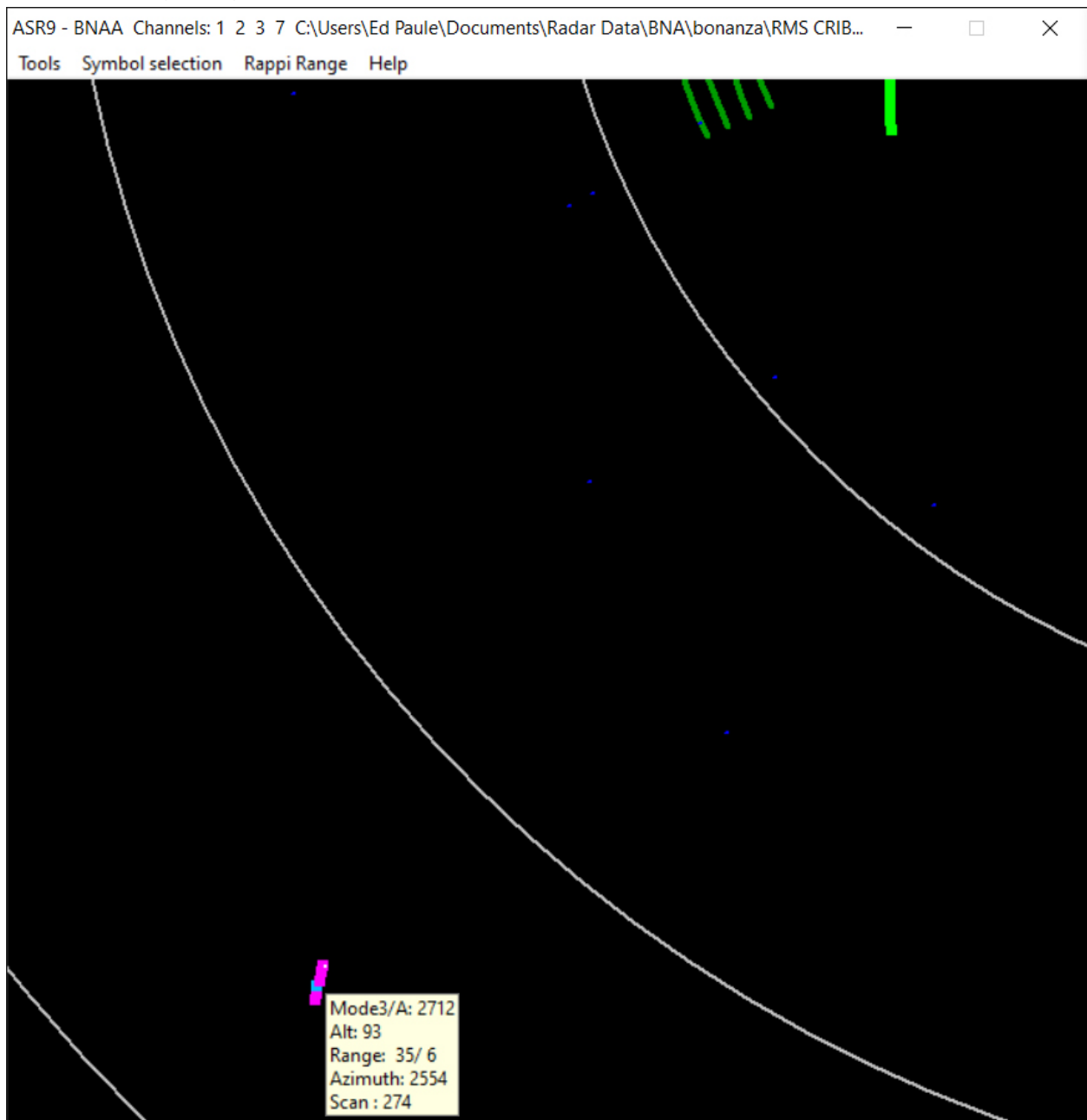
Scans 270-350 (1657Z to 1703Z)



Comparing the above image direct from the ASR-9 radar with the “Composite image from NTSB” shows the aircraft’s transponder was still in operation during the first 90 degrees of that right-hand turn but not during the rest of the apparent turn.

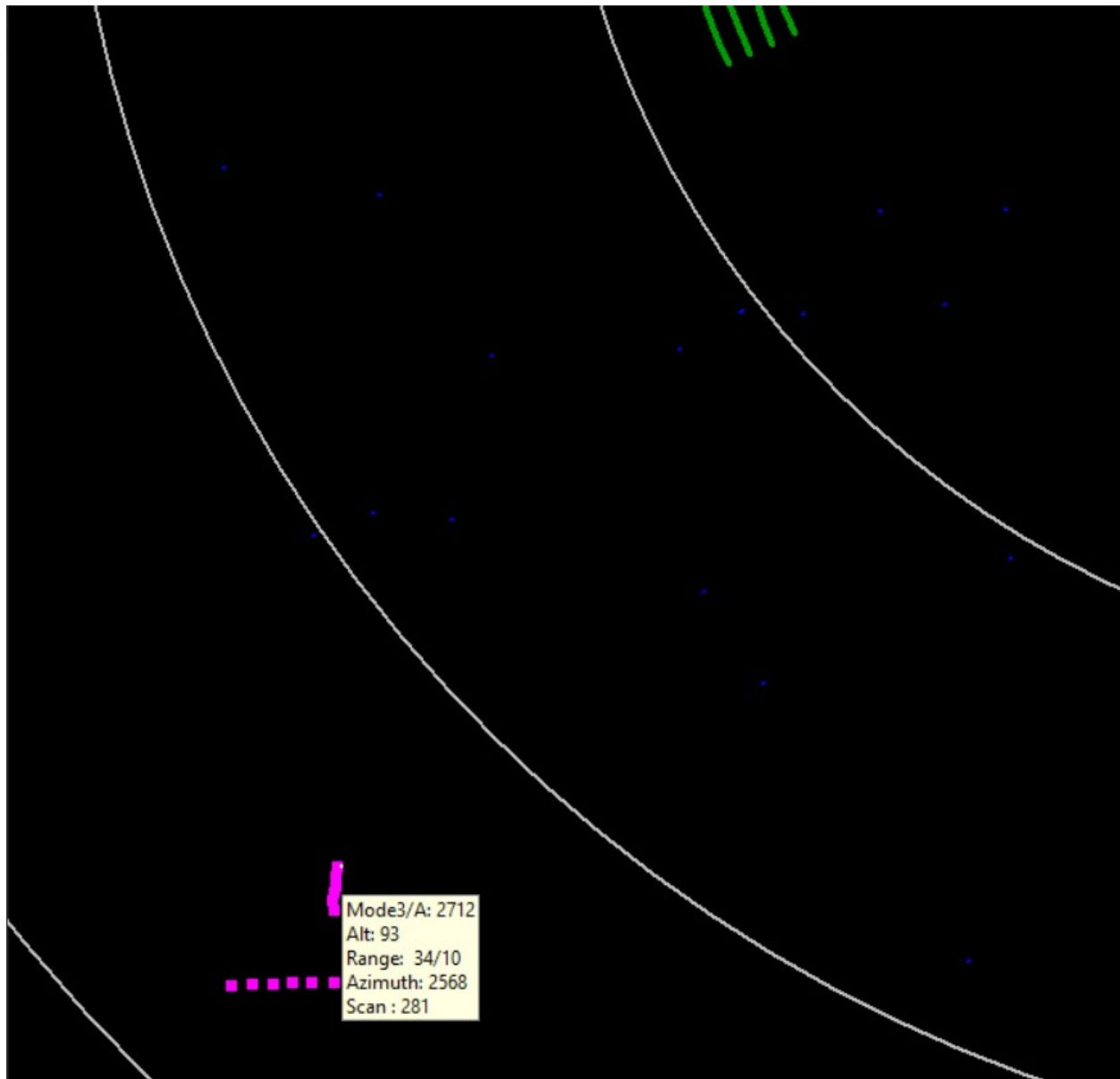
The following series of images each show six scans worth of data at a time. This is done to match the weather map update cycle and thereby provide the location of the aircraft and the weather being reported by the radar simultaneously.

Scans 270-275 (1657Z)



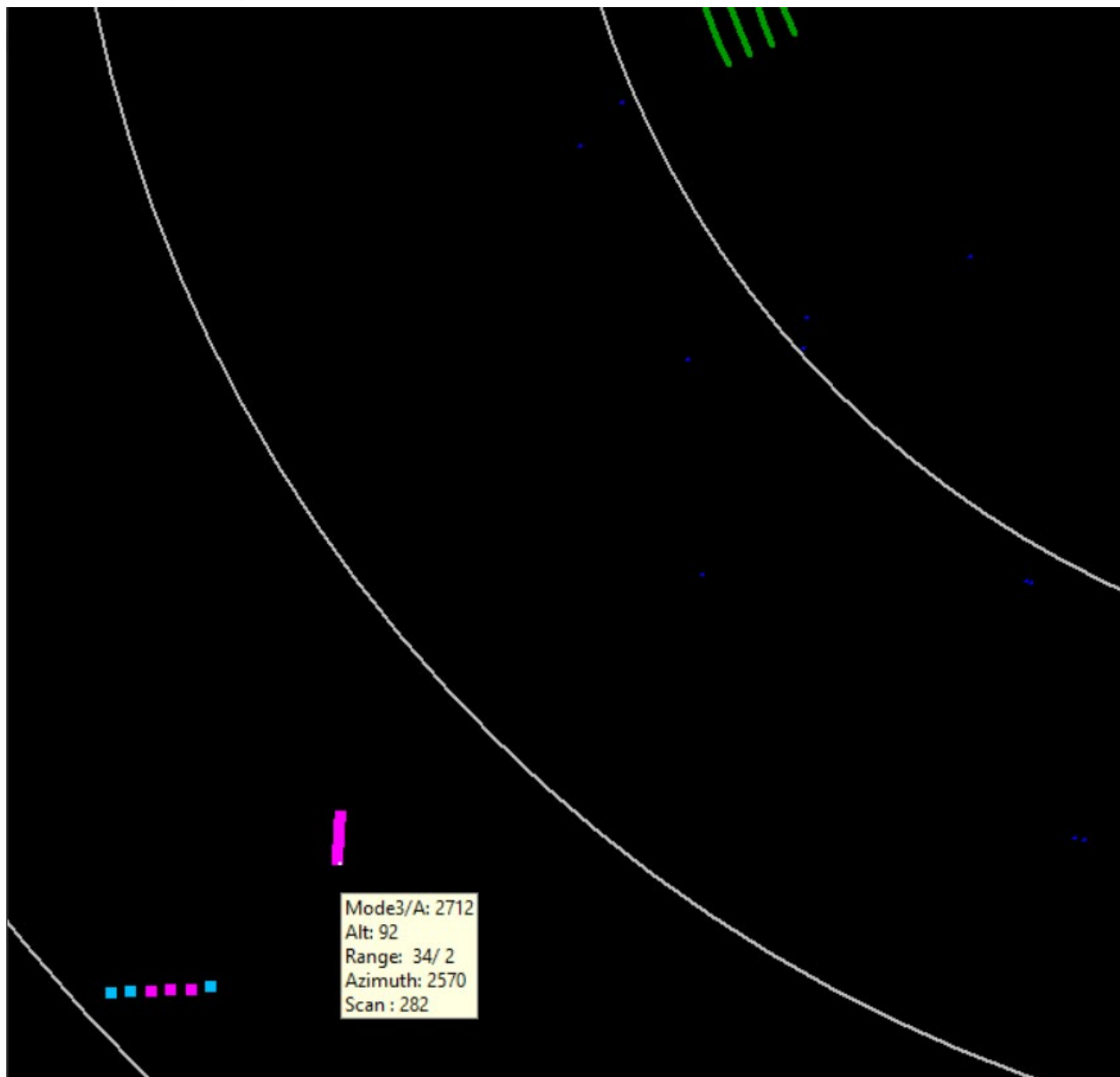
The radar shows clear skies ahead.

Scans 276-281 (1657Z)



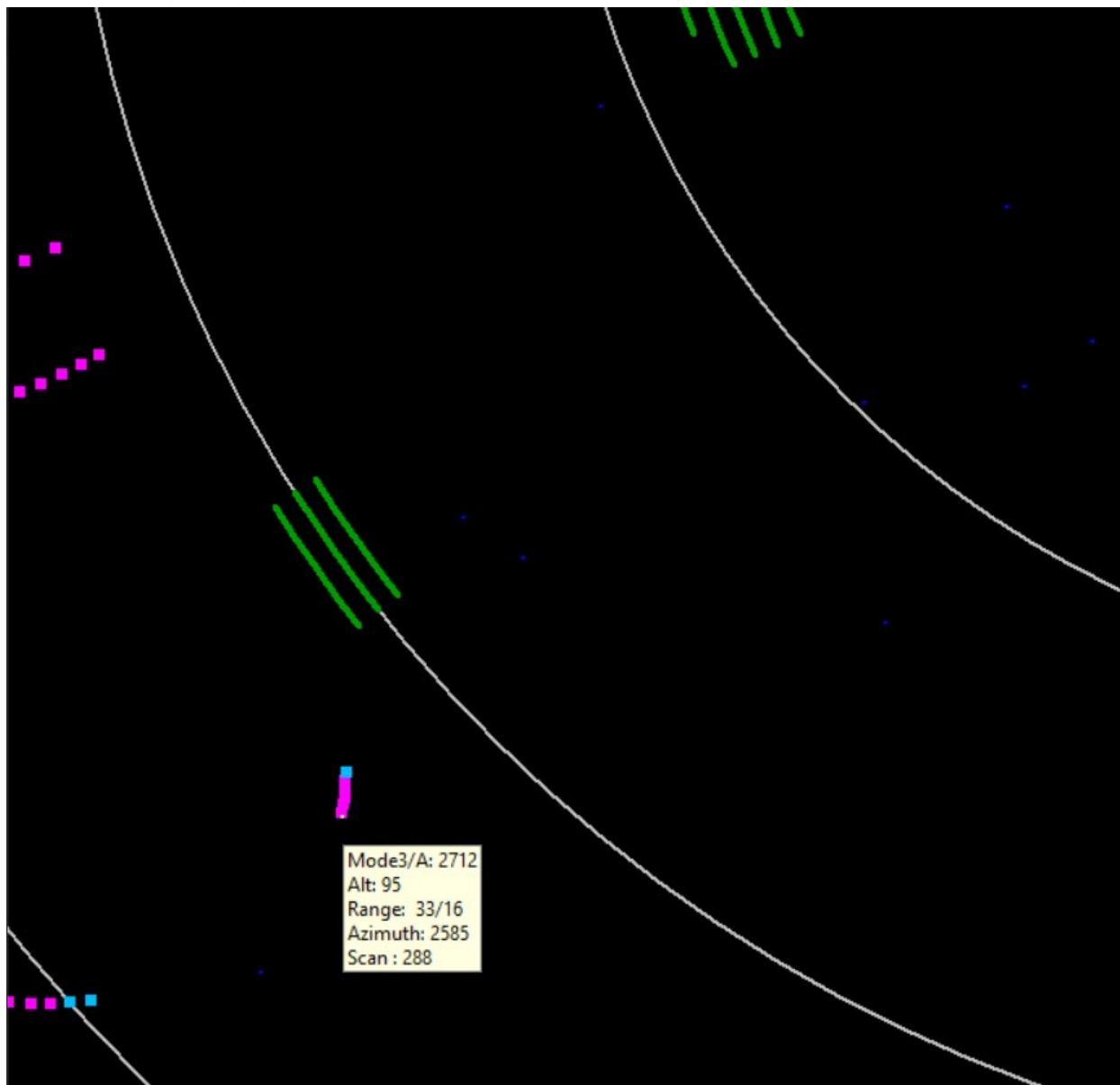
The radar shows clear skies ahead.

Scans 282-287 (1658Z)



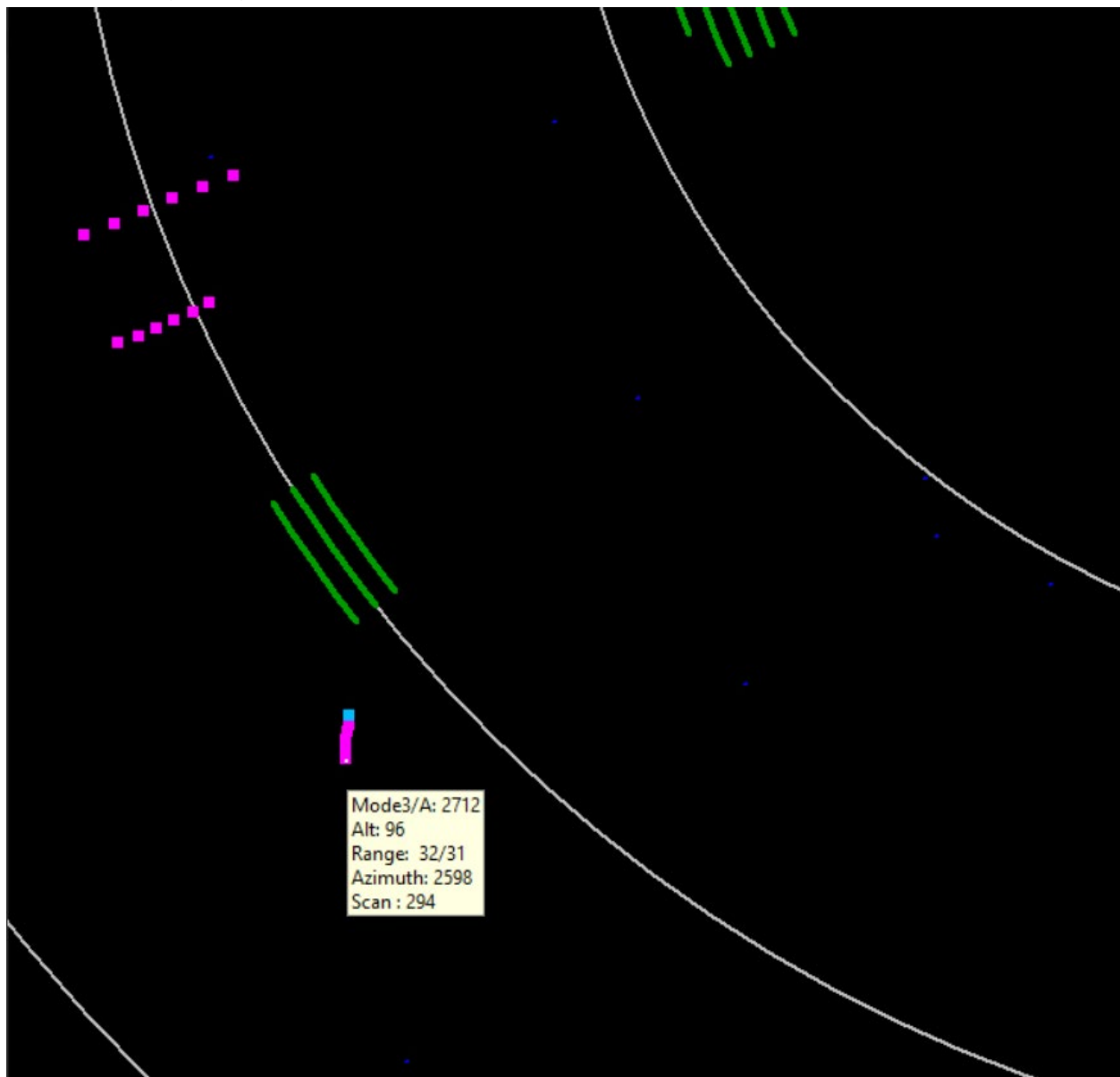
The radar shows clear skies ahead.

Scans 288-293 (1658Z)



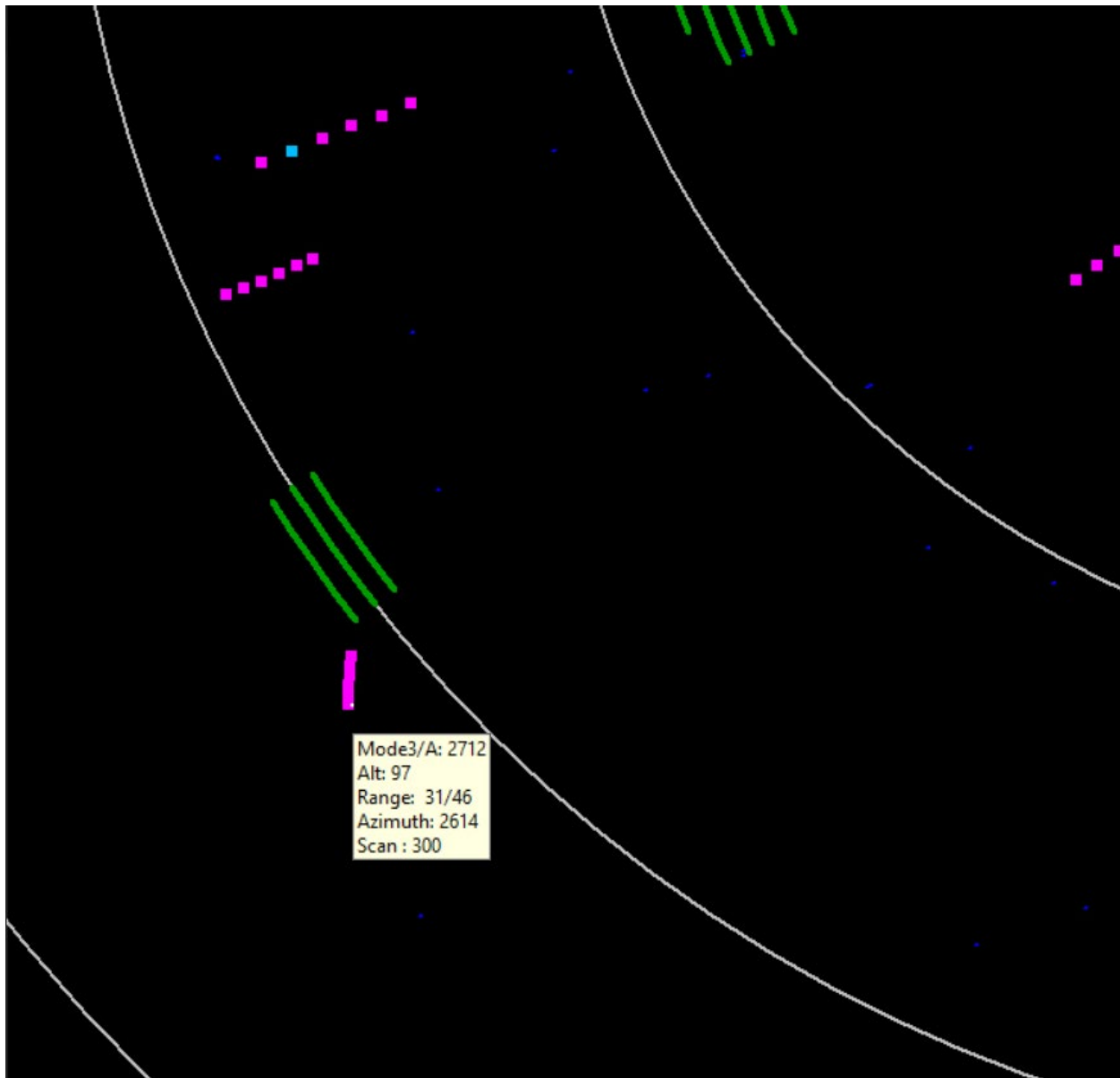
The radar shows a small area of level 1 weather ahead.

Scans 294-299 (1659Z)



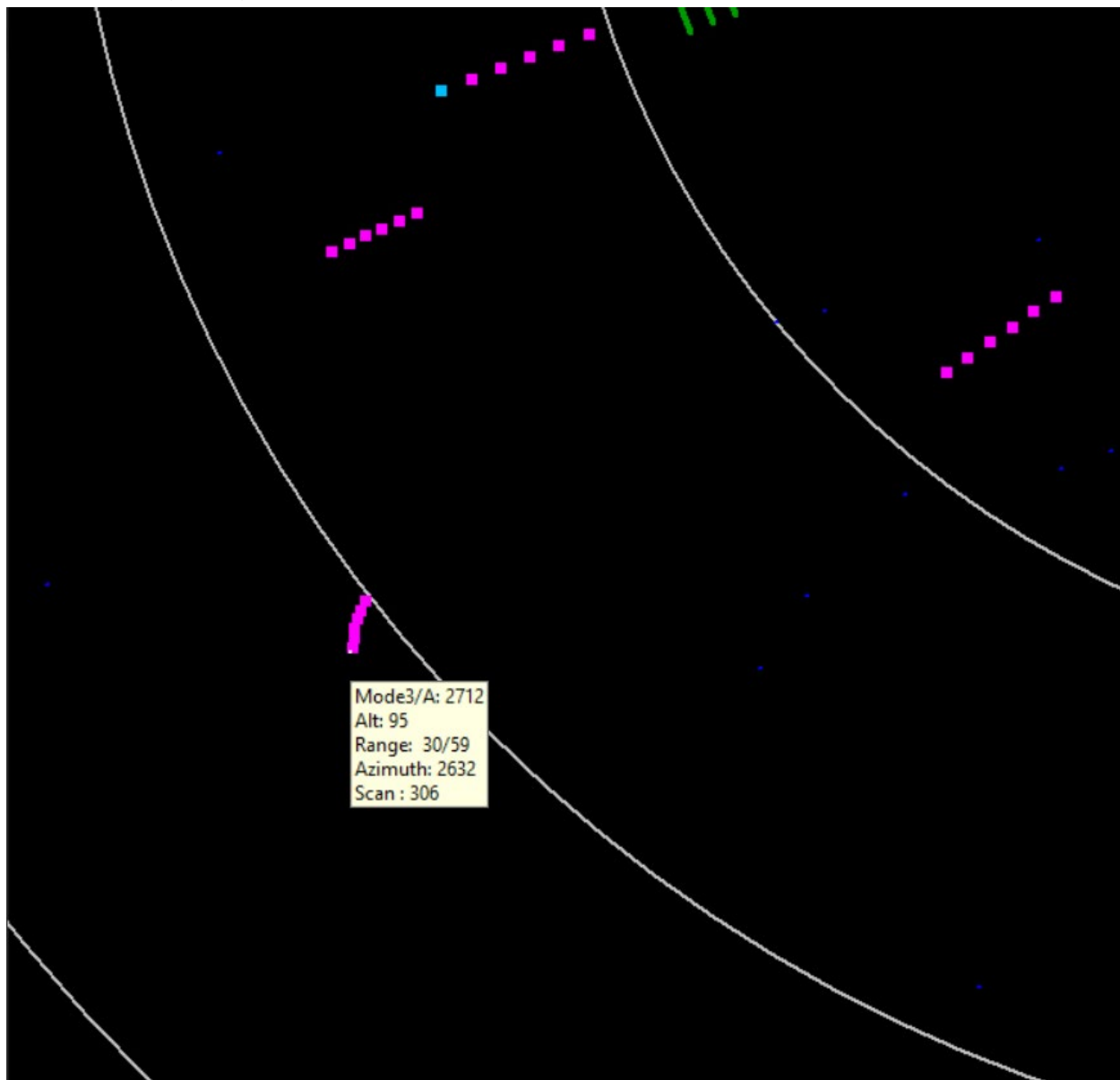
The radar shows a small area of level 1 weather ahead.

Scans 300-305 (1659Z)



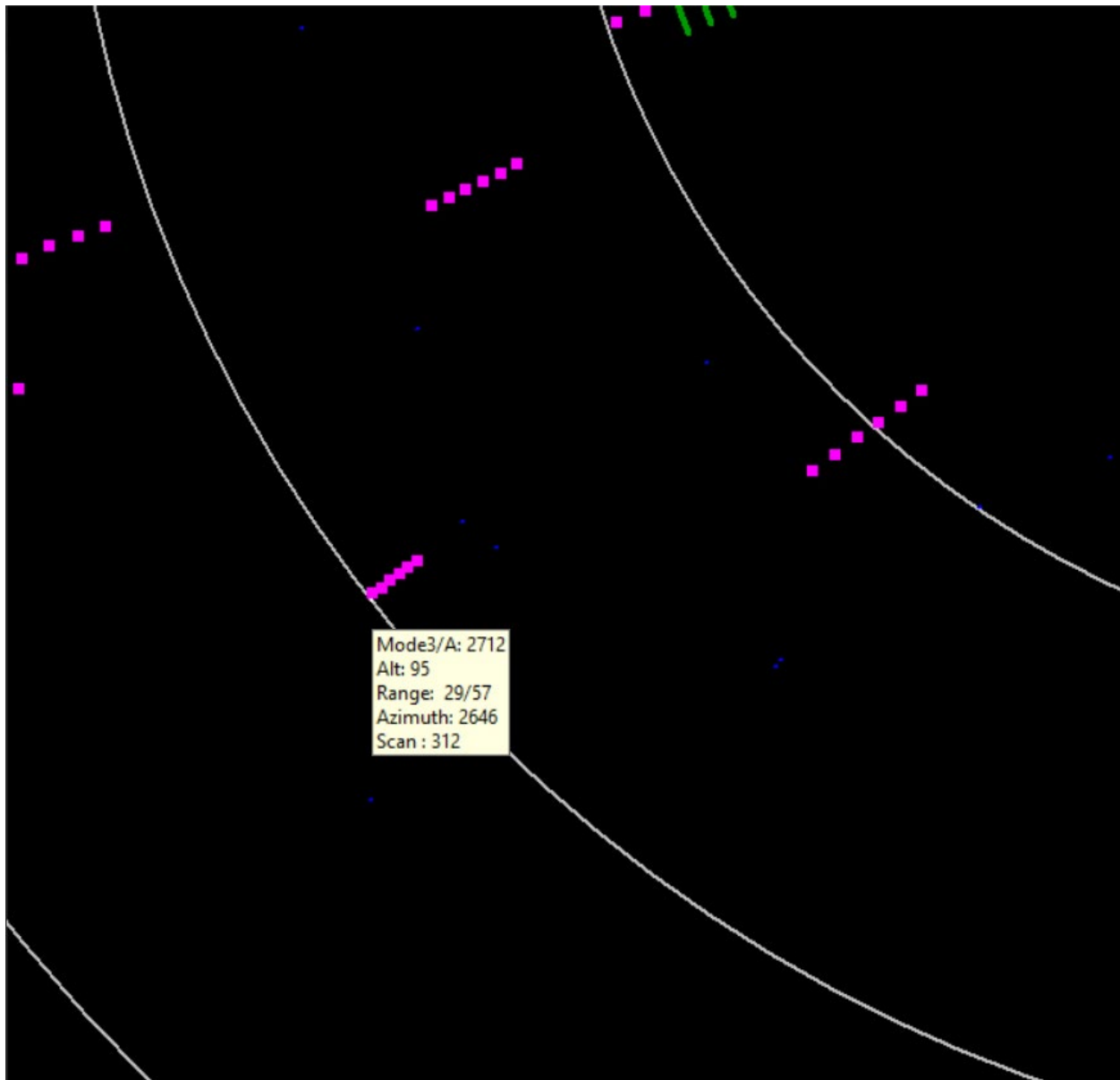
The radar shows a small area of level 1 weather directly ahead.

Scans 306-311 (1700Z)



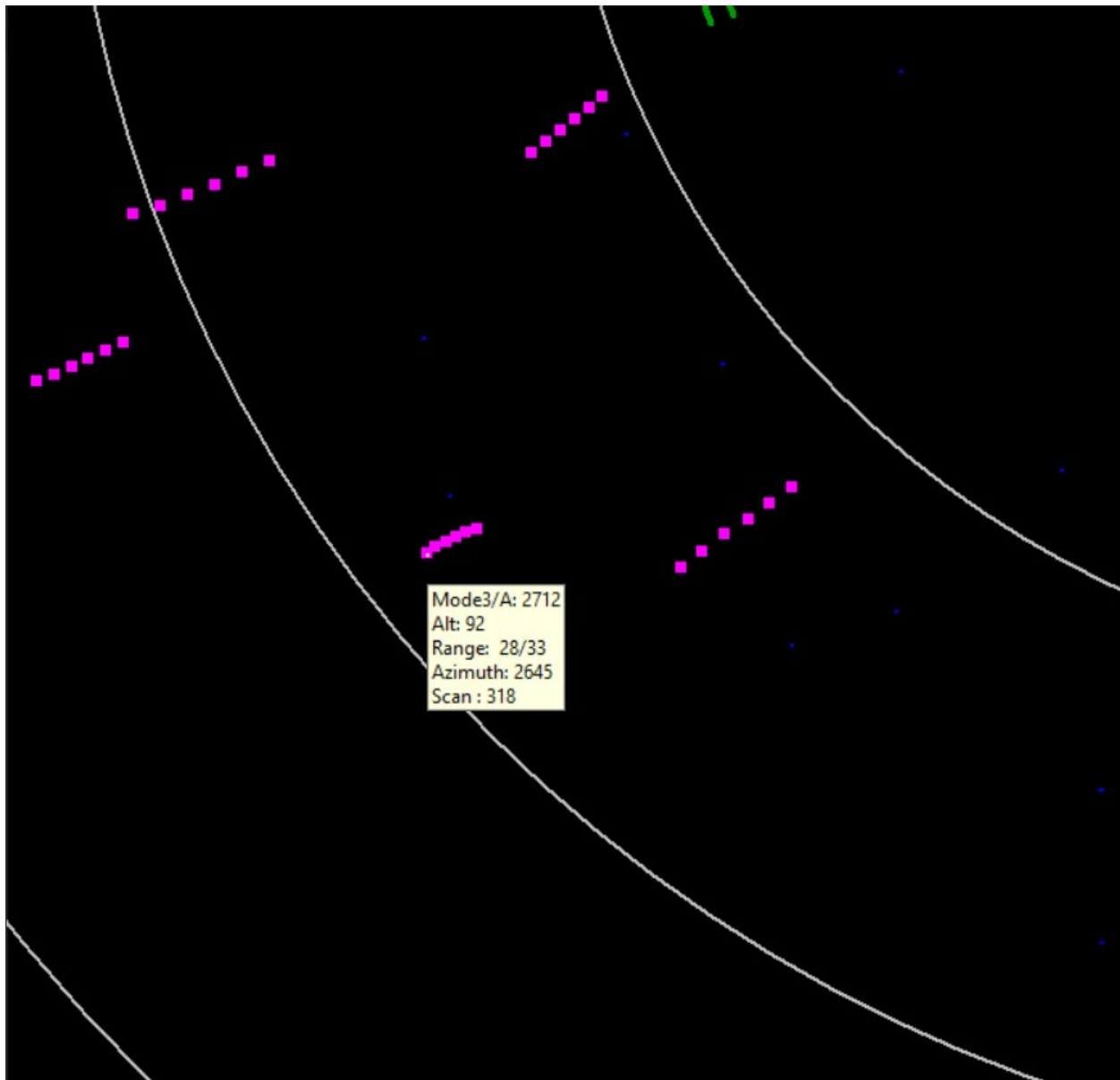
The level 1 weather is no longer being reported. The aircraft makes a small turn to the right.

Scans 312-317 (1700Z)



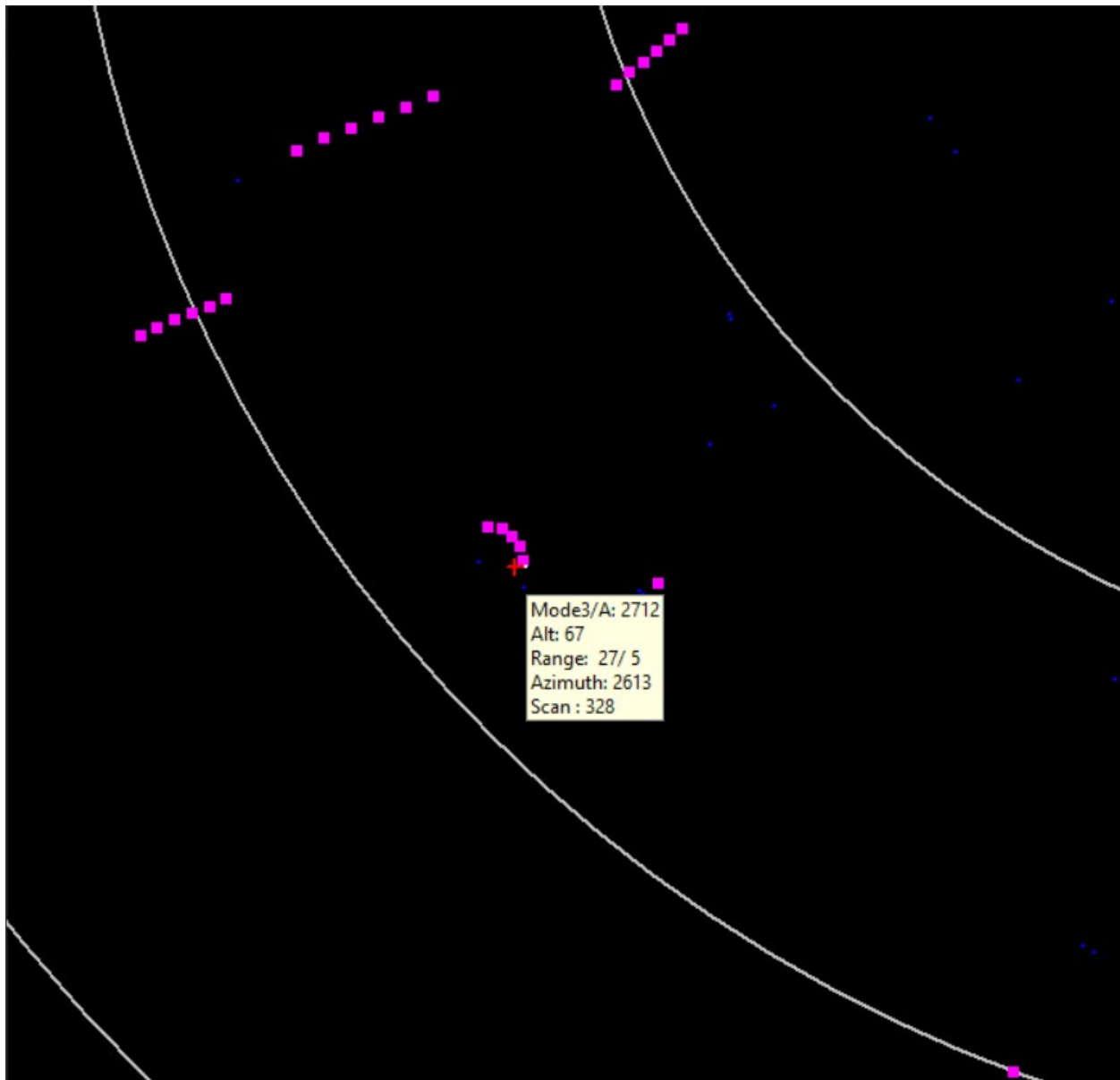
Although the radar is not reporting any weather ahead, there are two uncorrelated radar targets reported ahead. It is known that the edges of a storm can create false primary target reports. As such, it is possible that these uncorrelated reports are detections caused by the edge of the small weather cell shown in the NTSB image directly ahead of the aircraft.

Scans 318-323 (1700Z)



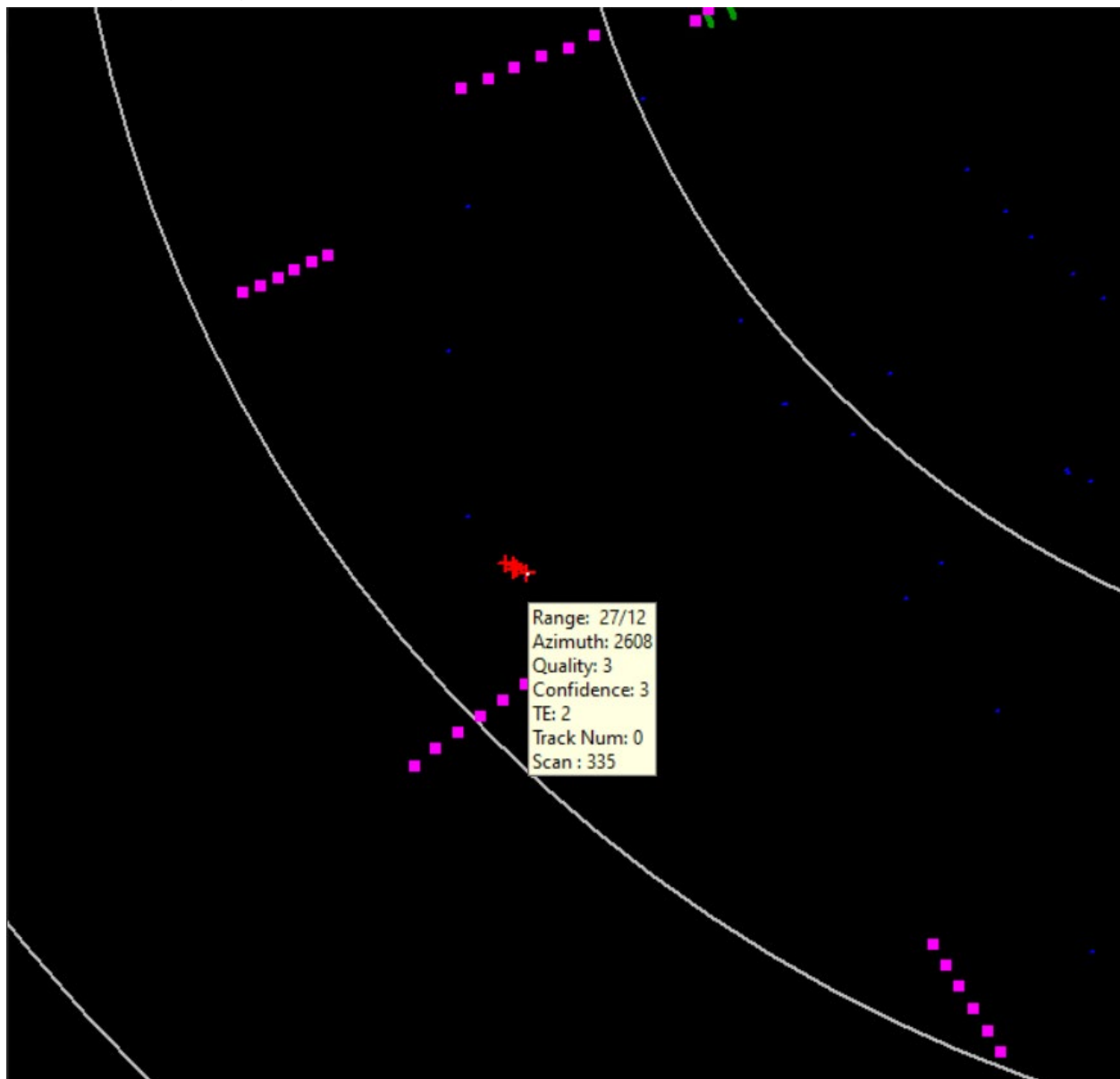
Another uncorrelated radar report appears to the left of the aircraft along the same line as the two uncorrelated reports in the previous image. If this does represent the edge of the weather cell, then the aircraft is now in it.

Scans 324-329 (1701Z)



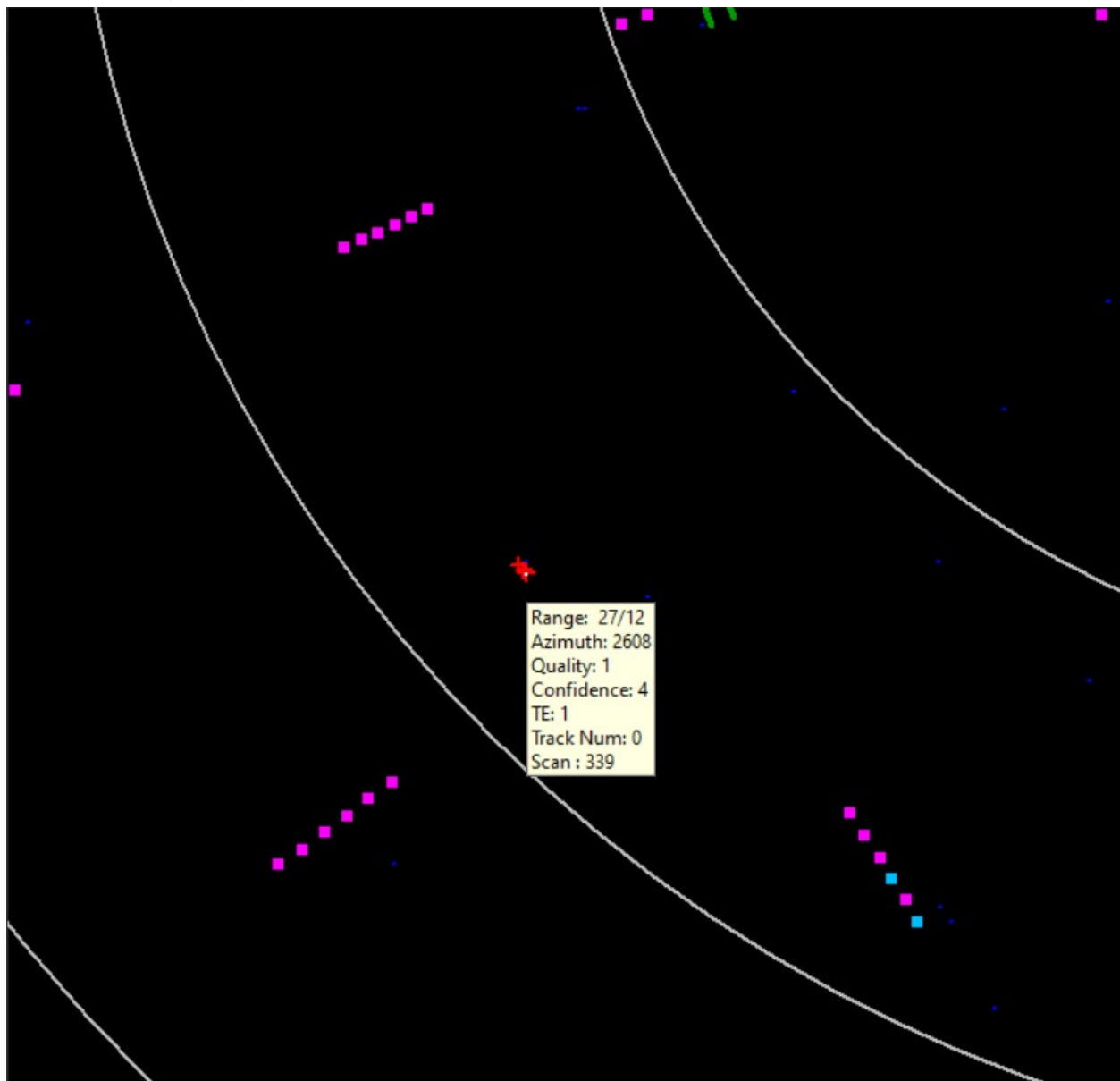
The aircraft makes a sharp 90-degree turn to the right. Shortly thereafter, the transponder stops replying to the system. Notice the radical change in altitude from the previous image. Structural failure of the aircraft has occurred, and it has begun to free fall. The radar continues to show no weather in the area.

Scans 330-335 (1701Z)



The wreckage of the aircraft is tracked as correlated radar targets as it falls from the sky.

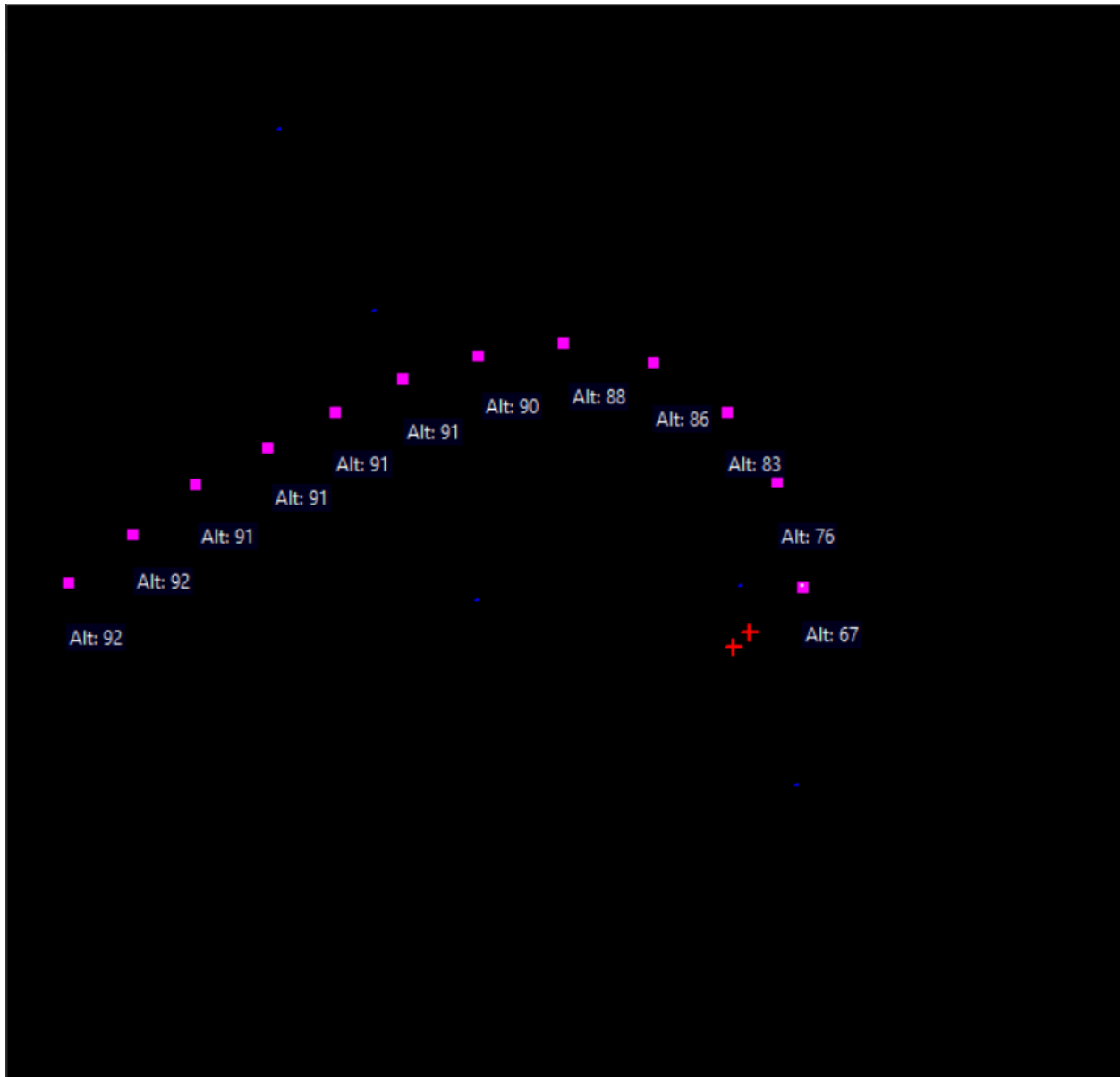
Scans 336-341 (1702Z)



The wreckage of the aircraft continues its decent to the Earth.

The following image zooms in on the last few scans of flight. The transponder's reported altitude (in hundreds of feet) is shown beneath each detection.

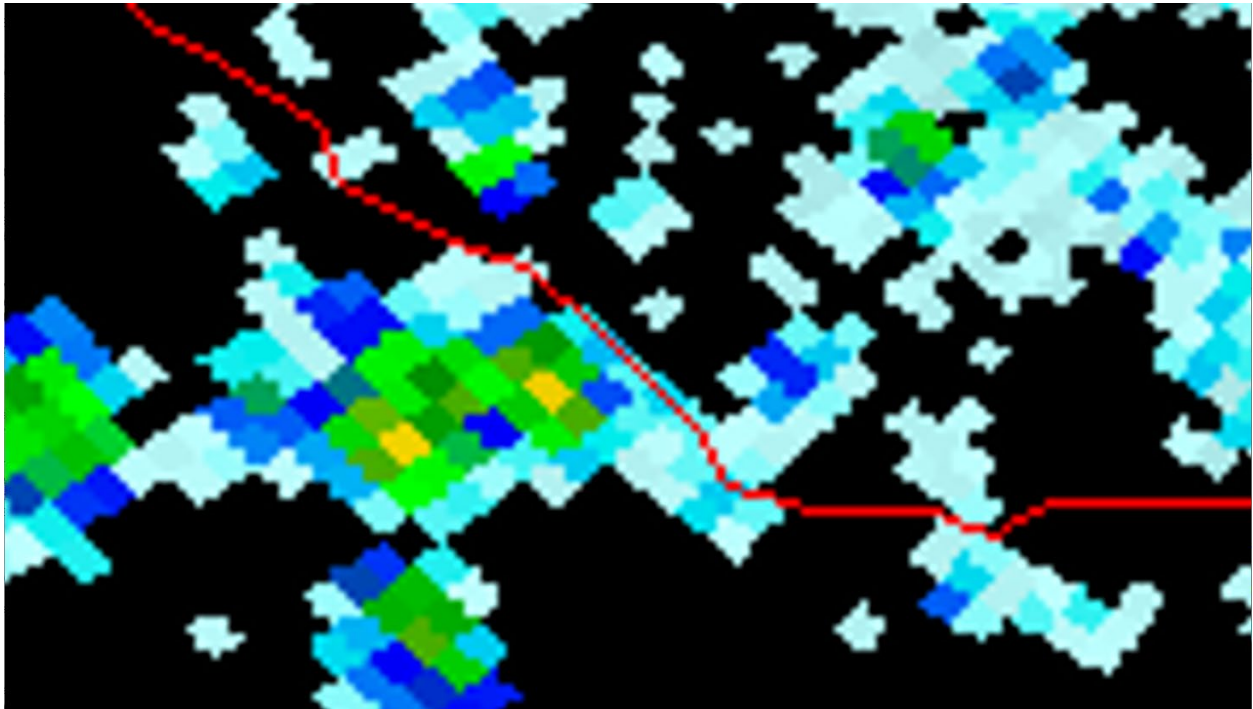
Scans 317-330 (1700Z to 1701Z)



It is unknown exactly when structural failure occurred, but shortly thereafter, the transponder lost power and ceased to report its altitude.

What did other weather radars see?

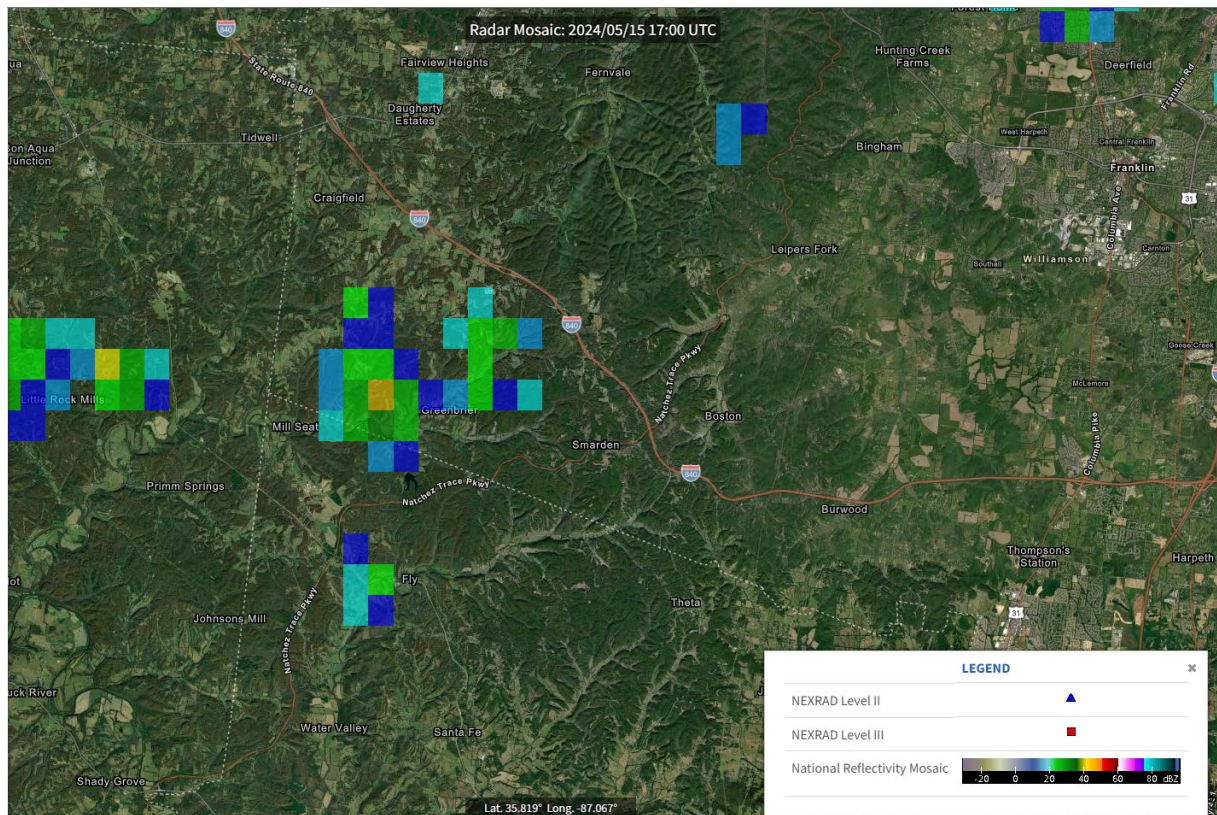
The below image comes from the KOHX NEXRAD pencil-beam weather radar and shows the weather in the area of interest at 1700Z. The red line follows the contours of I-840 southwest of Nashville.



The white and blue cells in this image are very weak weather that are less than the 18 dBz minimum threshold for declaring level 1 weather. The light green and green cells would correspond to level 1 weather with the dark green and yellow being level 2.

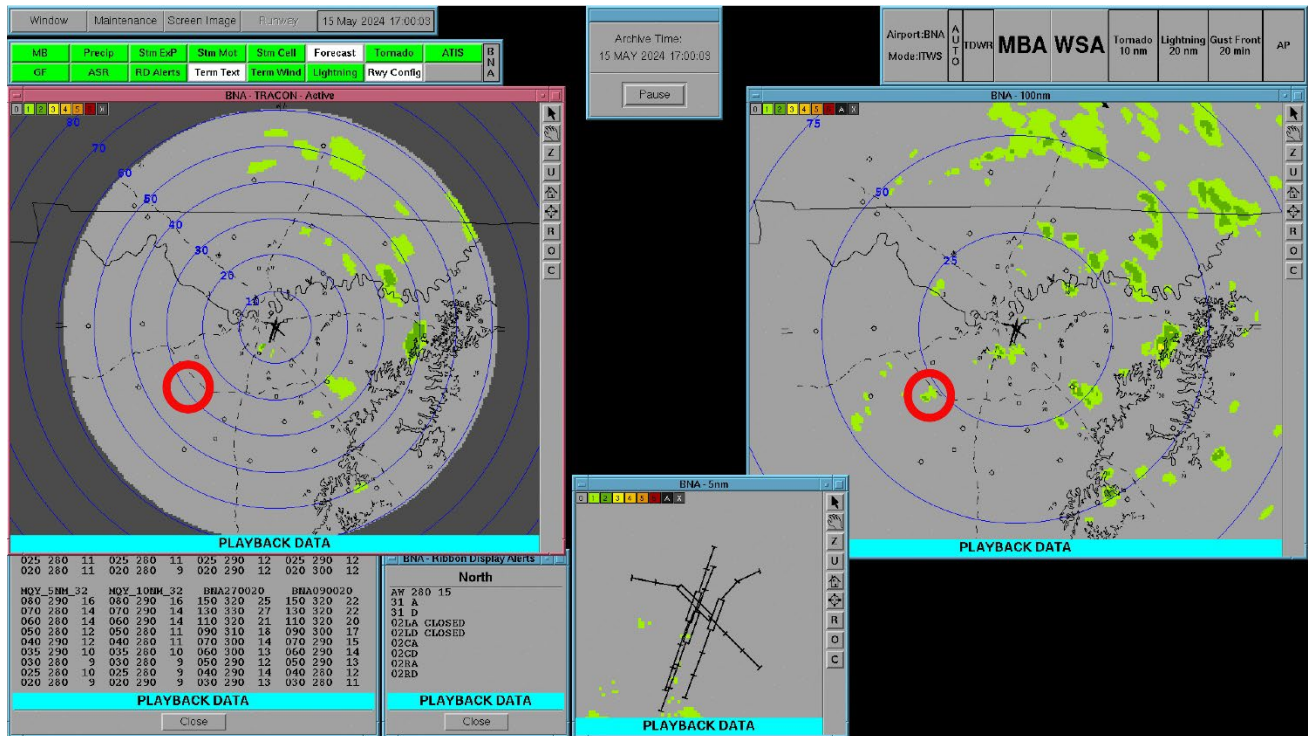
Of the two yellow cells shown, the one on the left appears to coincide with the level 1 weather that the ASR-9 did report at 1658 and 1659. The one on the right coincides with the cell the aircraft flew into that went unreported by the ASR-9.

The following image comes from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) website and shows the weather radar mosaic for the same time and place as the previous image (1700Z).



The orange (level 4) cell shown coincides with the yellow (level 2) cell seen at the left in the previous image. This is the weather that the ASR-9 did report as level 1. This radar mosaic image only depicts green (level 1) cells at the location the NEXRAD image showed as the right-hand yellow (level 2) cell which is where the accident occurred.

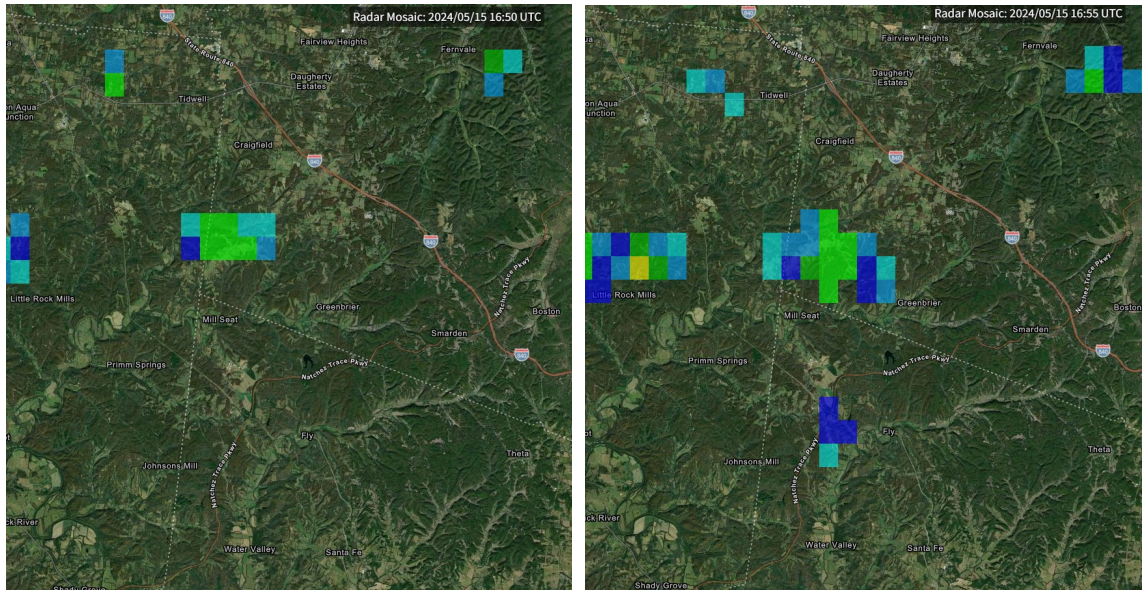
The following picture comes from ITWS. The image on the left shows the ASR-9 reported weather which is none (highlighted by the red circle). The image on the right is a combination of the Next Generation Weather Radar (NEXRAD) and the Terminal Doppler Weather Radar (TDWR) data and shows the cell on the left as level 2 and the cell on the right (the cell of interest) as level 1.



Looking at the other areas north and east of Nashville and comparing the ASR-9 presentation with the combined NEXRAD and TDWR presentation, you can see that the ASR-9 appears to be slightly underreporting the weather. According to ITWS personnel, this difference is within the normal range of deviation.

The following images show the weather mosaic at five-minute intervals for both before and after the event.

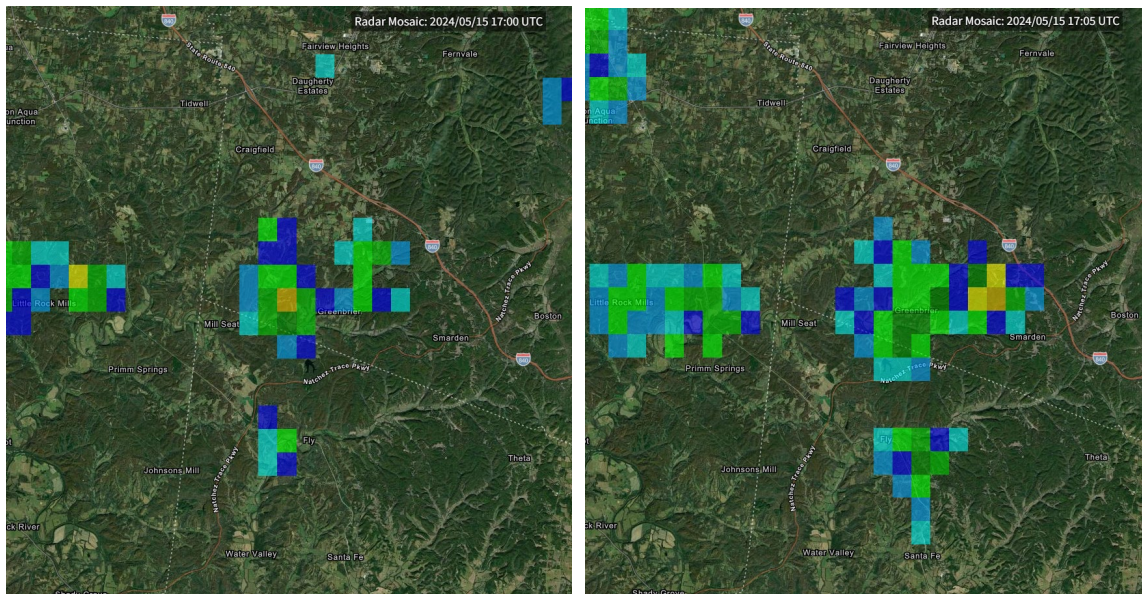
NOAA NCEI mosaic 1650Z and 1655Z:



At 1650Z, the left-hand storm is just starting to form (level 1).

At 1655Z, the left-hand storm has grown slightly in size (still level 1).

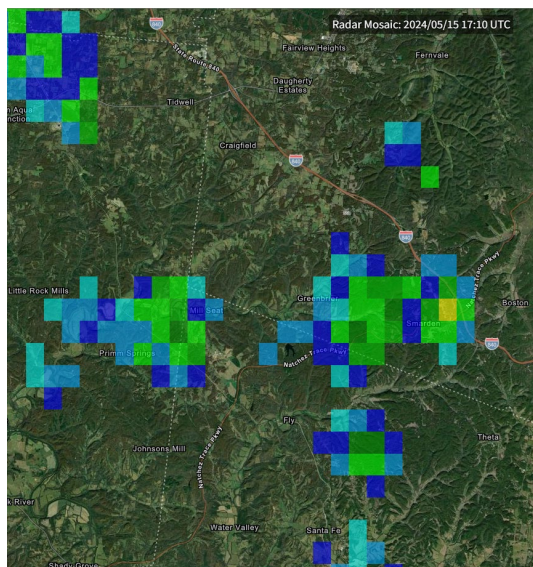
NOAA NCEI mosaic 1700Z and 1705Z:



At 1700Z, the left-hand storm shows a level 4 center cell whilst the right-hand storm starts at level 1.

At 1705Z, the left-hand storm has dropped to level 2 whilst the right-hand storm peaks at level 4.

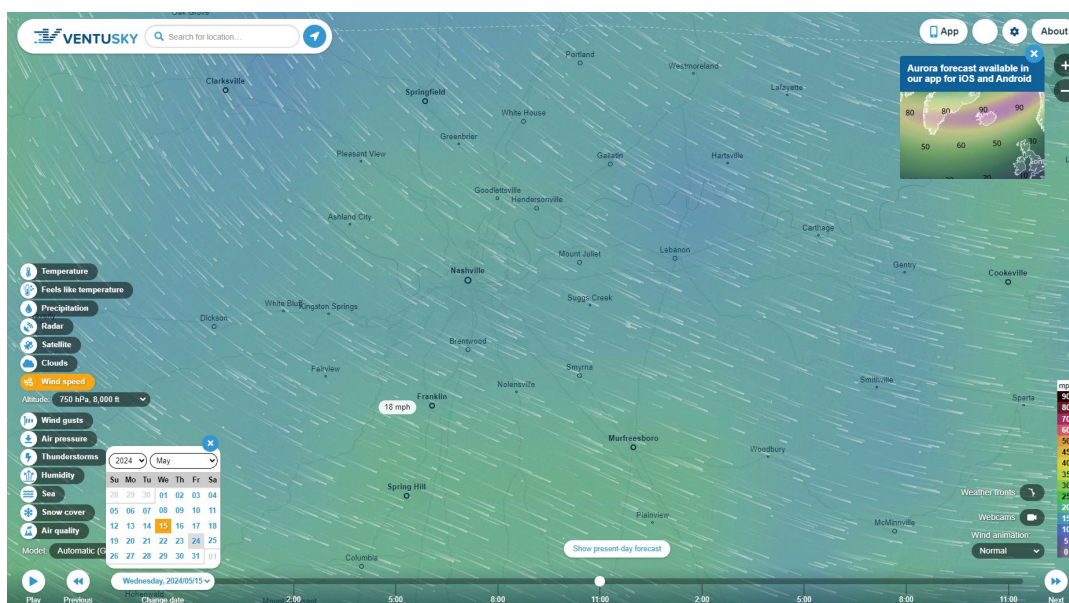
NOAA NCEI mosaic 1710Z:



At 1710Z, the right-hand storm has dropped to a level 3 center cell.

Watching the above images as a time-lapsed video shows the storms in motion in a southeasterly direction. The right-hand storm that appears to have contributed to the accident rapidly increased in intensity from 1700Z (level 1) to 1705Z (level 4). The exact weather level at the exact time of the disaster is unknown.

The below image from Ventusky shows the prevailing winds at 8000-feet elevation being at 18 knots in a southeasterly direction. With the radar to the northeast, this southeasterly direction of movement is tangential to the radar.



Why didn't the ASR-9 report this weather? Was it broken?

The BNA ASR-9 was reporting a Weather Minimum Discernable Signal (MDS) Failure alarm (914) which indicates a problem with the circular polarization (CP) pathway in the receiver. The facility was aware of this and had ordered the parts needed to fix it. As circular polarization was broken, the system was operating in manual linear polarization (LP) mode. This is the appropriate method to prevent the system from operating in the faulty circular polarization mode.

Note that the purpose of circular polarization is to improve the radar's ability to detect aircraft through rain. CP is better than LP at drilling through the rain to detect targets at further range. The thresholds used internally to convert the magnitude of the weather returns into an NWS weather level are biased accordingly. Thus, a storm of a given intensity should be reported at the same weather level regardless of which polarization is in operation.

Under normal operating conditions, the ASR-9 would automatically switch to CP when 8% of the coverage volume contains level 2 or greater weather. At the time of the incident, less than 1% of the airspace contained level 2 or higher weather. As such, the system would have been operating in LP even if CP wasn't broken.

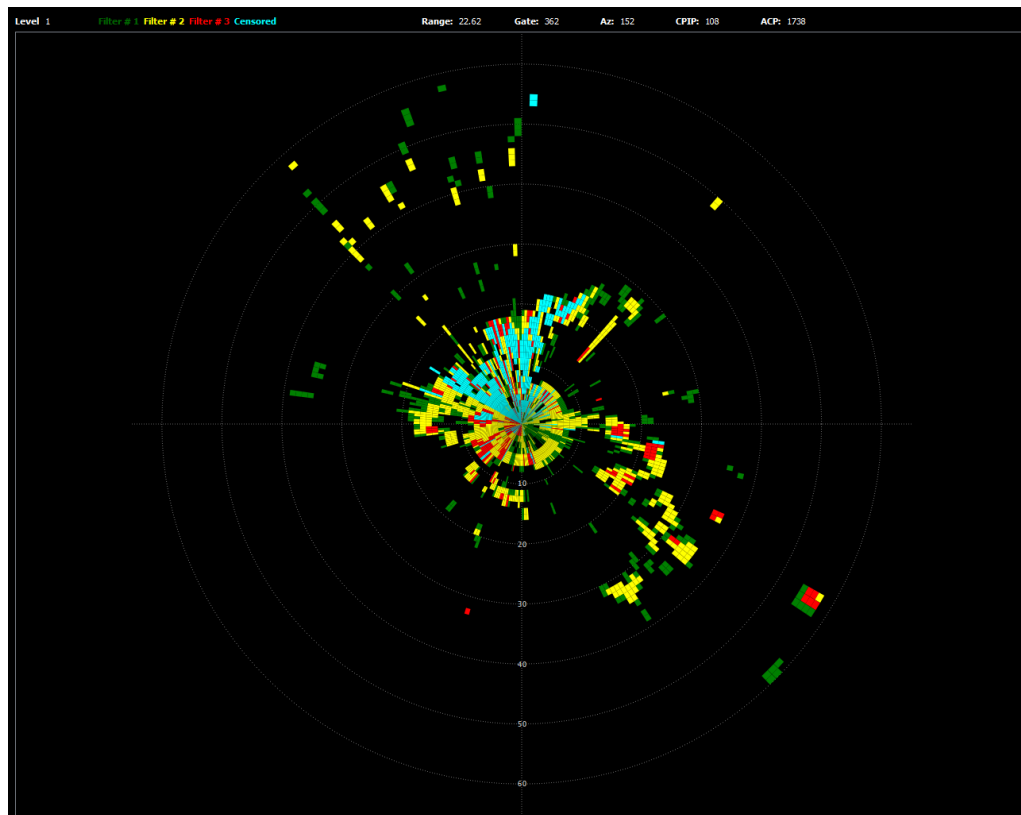
The image below shows a segment of the BNA ASR-9 alarm log for the time around the event.

2024-05-15 12:47:40	WEU31	ZME	ASR	BNA	C934	Normal	Wx Rec MDS Fail	R - Return
2024-05-15 12:47:50	WEU31	ZME	ASR	BNA	C934	** A L A R M **	Wx Rec MDS Fail	N - Unacknowledged Alarm
2024-05-15 13:20:08	WEU31	ZME	ASR	BNA	C7B2	** A L A R M **	SCIP A COMM Fault	N - Unacknowledged Alarm
2024-05-15 13:20:21	WEU31	ZME	ASR	BNA	C7B2	Normal	SCIP A COMM Fault	R - Return
2024-05-15 14:34:57	WEU31	ZME	ASR	BNA	C7B2	** A L A R M **	SCIP A COMM Fault	N - Unacknowledged Alarm
2024-05-15 14:35:07	WEU31	ZME	ASR	BNA	C7B2	Normal	SCIP A COMM Fault	R - Return
2024-05-15 14:42:13	WEU31	ZME	ASR	BNA	9120	On	Local RMS Terminal	C - State Change
2024-05-15 14:59:27	WEU31	ZME	ASR	BNA	9120	Off	Local RMS Terminal	C - State Change
2024-05-15 15:41:44	WEU31	ZME	ASR	BNA	C7B3	** A L A R M **	SCIP B COMM Fault	N - Unacknowledged Alarm
2024-05-15 15:41:57	WEU31	ZME	ASR	BNA	C7B3	Normal	SCIP B COMM Fault	R - Return
2024-05-15 15:46:42	WEU31	ZME	ASR	BNA	C7B2	** A L A R M **	SCIP A COMM Fault	N - Unacknowledged Alarm
2024-05-15 15:46:55	WEU31	ZME	ASR	BNA	C7B2	Normal	SCIP A COMM Fault	R - Return
2024-05-15 16:28:57	WEU31	ZME	ASR	BNA	C7B2	** A L A R M **	SCIP A COMM Fault	N - Unacknowledged Alarm
2024-05-15 16:29:07	WEU31	ZME	ASR	BNA	C7B2	Normal	SCIP A COMM Fault	R - Return
2024-05-15 17:17:03	WEU31	ZME	ASR	BNA	C7B2	** A L A R M **	SCIP A COMM Fault	N - Unacknowledged Alarm
2024-05-15 17:17:16	WEU31	ZME	ASR	BNA	C7B2	Normal	SCIP A COMM Fault	R - Return
2024-05-15 17:34:13	WEU31	ZME	ASR	BNA	C934	** A L A R M **	Wx Rec MDS Fail	N - Unacknowledged Alarm
2024-05-15 17:34:13	WEU31	ZME	ASR	BNA	C934	Normal	Wx Rec MDS Fail	R - Return

Analysis of the alarm logs shows a large number of communication faults occurring during the days before and after the event. This indicates that a small number of messages were being lost in transmission from the radar site to the TRACON, but none of these alarms were active at 1701Z. Also, recordings taken from the radar site itself show that the offending storm was not being output by the radar site. Thus, this was not a factor in STARS not showing the weather.

Otherwise, the system appears to have been operating normally.

The ASR-9 uses a Clear Day Map (CDM) to suppress false weather from reflections off the ground. The following image depicts the Clear Day Map in use by the BNA system at the time of the accident. There are no CDM cells in the area of interest (27 nmi to the southwest), so this is not a factor.



If there was a problem with converting incoming weather data into the proper weather levels, then this would be detected during the semi-annual Weather Operations Check in the ASR-9 Handbook.

The Performance Monitoring log shows that BNA had successfully accomplished the Weather Operations Check on February 23, 2024. Knowing that this check was important to this investigation, the facility was asked to perform the check again. This was done on May 29, 2024 and the results showed that the system passed the check again.

With the Weather Operations Check passing, the primary reason this storm wasn't reported is "spatial smoothing." Spatial smoothing is one of a series of steps required in the processing of weather data. The image below is taken from the ASR-9's specification, FAA-E-2704B which shows the requirement for spatial smoothing.

3.21.13.1 . . . Temporal Smoothing. . . . This function shall develop a weather map with 1/2 nmi range granularity and 1.4 degrees azimuth granularity, approximating the median weather level detected during 3 pairs of scans (scans 1 and 2, 3 and 4, 5 and 6). Weather level for a scan pair shall be generated by replacing odd scan data (0, level 1, or censored) with any even scan data other than zero (levels 2-6 or censored). If the weather levels reported on the first two scan pairs match, this level shall be stored in this map. If they do not match, the level stored in this map shall be the smaller of the levels on the first two scan pairs unless the third scan pair reports a higher level, in which case, the level stored shall be one higher than the smaller level of the first two scan pairs. If one of the three input levels is censored, the smaller of the other two shall be stored. If more than one of the three input levels is censored, the map is censored.¶¶

3.21.13.2 . . . Spatial Smoothing. . . . This function shall develop a weather map with 1/2 nmi range granularity and 1.4 degrees azimuth granularity defining the level of weather equalled or exceeded in a programmable fraction of a 9 cell cluster (each cell and its 8 neighbors). Censored cells shall be ignored in both the numerator and denominator of the fraction, except that the output data shall be designated as censored when the denominator is too small to provide meaningful data.¶¶

3.21.13.3 . . . Contouring. . . . This function shall develop and report a single weather map with 1/2 nmi range granularity and 1.4 degrees azimuth granularity defining the highest level of weather detected in 3.21.13.2 in each 9 cell cluster (each cell and its 8 neighbors). When possible, if all 9 cells are censored, the level output shall be the level contoured at an adjacent range or azimuth where this condition does not exist. Collection of all weather data shall be completed every six scans or less at the radar site and completely processed and transferred (all 30,720 cells) into the SCIP within three scans or less of completion of collection of weather data. When the SCIP parameters are chosen to minimize

The “programmable fraction” stated in the specification is known as the “smoothing parameter.” It is set at a value of 5 at all ASR-9 facilities. This is the value that BNA was using at the time of the incident. This means that five out of the nine cells in a cluster must be of a given level or higher for that level to be reported.

Since the very first ASR-9 was commissioned in 1989, this parameter has had a value of 5. Optimization testing in Huntsville, AL by the FAA and the Massachusetts Institute of Technology (MIT) Lincoln Laboratories found this to be the optimum value.

To show the effects of spatial smoothing, let’s assume that the NOAA NCEI mosaic was truth, and that the ASR-9 detected it as such after the temporal smoothing step just prior to the spatial smoothing step. The cell size in the NOAA data is 0.5 nmi wide and 0.7 nmi tall. The ASR-9 cell size is 0.5 nmi deep in range and at the distance of 27.1 nmi from the ASR-9, the 1.4-degree cell size in azimuth is 0.66 nmi. This makes for a convenient one-to-one relationship.

The below image is zoomed-in on the two storms that have been called “left-hand” and “right-hand” in the previous descriptions. This image is from the 1700Z NOAA NCEI mosaic. The table to the right shows this same information converted into National Weather Service (NWS) weather levels for each corresponding cell.



0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	0
0	1	1	0	0	0	1	0	0
0	1	4	1	0	0	1	0	0
0	1	2	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0

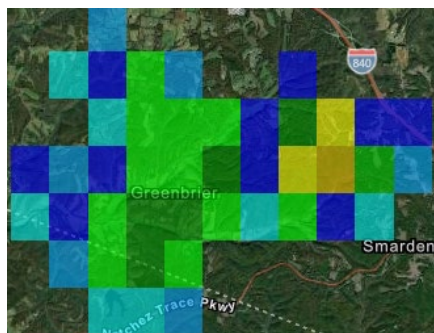
Here is the map after the spatial smoothing (5-of-9) algorithm is applied:

0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0
0	0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

For example, when performing spatial smoothing on the cell showing level 4, its eight neighbors consist of six cells at level 1, one cell at level 2 and one cell at level 0. Level 1 is the highest level that five of these nine cells contains. Thus, level 1 is output.

For the right-hand storm that only shows four level 1 cells, this is one short of the required five cells. As such, level 0 is reported for that area.

As another example, let's perform spatial smoothing on the 1705Z data which had shown the left-hand storm reduced to level 2 whilst the right-hand storm had increased to level 4.



0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0
0	0	0	1	1	1	0	2	3	0
0	0	0	1	1	2	0	3	4	1
0	0	1	2	2	1	0	1	0	0
0	0	1	2	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Here is the map after the spatial smoothing (5-of-9) algorithm is applied:

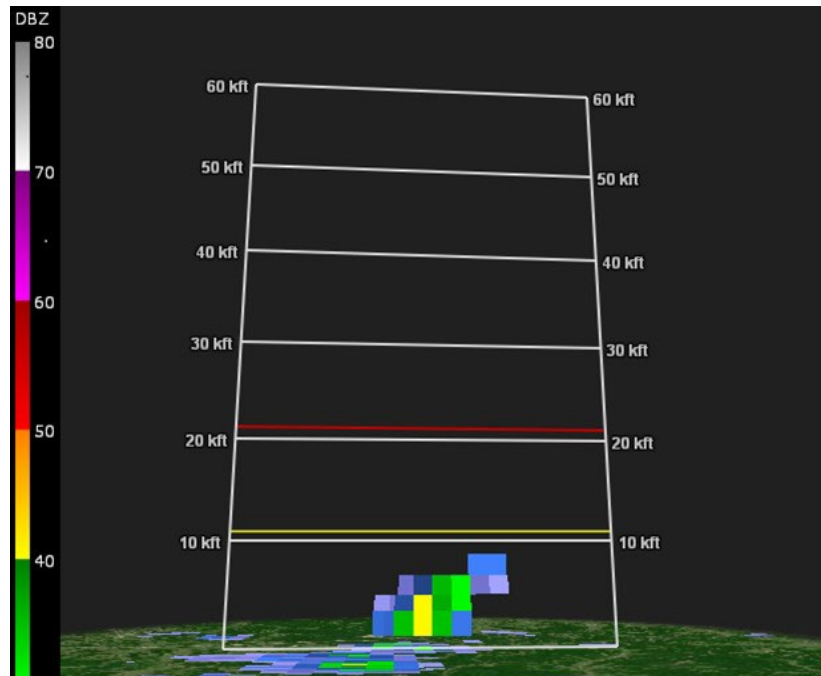
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	0	0	0	1	0
0	0	0	1	1	1	1	1	1	0
0	0	1	1	1	1	0	0	0	0
0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Everything gets knocked down to level 1 at best as there are never five level 2 or higher cells in the same nine-cell cluster.

In other words, the high intensity portion of these storms was too small in area to survive the spatial smoothing process. It would be knocked down to level 1 at best.

The secondary reason for the ASR-9 not reporting these storms is beam-fill loss. As a fan-beam radar, the ASR-9 sees the entire vertical column of air and rain at the same time. The radar assumes that any rain seen is filling most of that vertical space. If the altitude of the storm clouds is low, then the reflectivity of the rain falling below the clouds is inherently averaged with the clear air (zero reflectivity) above the clouds.

The following image from NEXRAD shows a vertical cross-section of the offending storm:



With the more intense rain capped at 5000 feet and the cloud tops at 8000 feet, less than half of the ASR-9's vertical beam is filled with rain. As the system assumes that the rain is filling most of its beam (20,000 feet), the system will detect a less intense weather level overall.

This means that the weather levels for each cell that were input to the spatial smoothing algorithm were actually less than those shown in the above example.

Conclusions

Although the BNA ASR-9 was having issues with the circular polarization path and was experiencing intermittent loss of data in the communications path between the radar and the TRACON, these issues did not affect the weather presentation provided to STARS at the time of the tragedy.

The primary reason the storm was not displayed to the controller was that it was too small to survive the spatial smoothing processing in the ASR-9. A secondary reason is that the storm was at a low altitude and thereby reduced by beam-fill loss.

In all probability, beam-fill loss was responsible for knocking the level 4 weather cell down to level 2 and spatial smoothing was responsible for knocking it from level 2 down to 0.

With the aircraft flying at 9000 feet at the time of the incident and the storm's cloud tops being at 8000 feet, the aircraft was above the storm when the tragedy occurred.

Recommendations

When compared to ITWS, the BNA ASR-9 appears to be slightly underreporting the weather. Further evaluation should be performed on the BNA ASR-9 to see if this is consistently so. If it is, then an experiment using a smoothing parameter value of 4 or less should be performed to see if that brings the ASR-9's weather presentation more in line with the ITWS presentation.

There is a program in place called Terminal Precipitation on the Glass (TPoG) that is looking to provide a better weather product to STARS for them to display instead of the ASR-9's weather product.