AjT, Inc.

Airborne Weather Radar Pilot's Operating Guide

$3.50

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CAUTION: All of the information, charts and recommendations in this Guide assume an operation in the Continental United States. It is also assumed that the radar and radome are properly calibrated, with the gain control at the calibrated position and a weather mode selected.

Thunderstorm Avoidance Guidelines

Certainly avoid all contouring echoes if possible. But, **whether it's contouring or not**, consider the following four guidelines:

1. If your Hazard Index exceeds five, expect explosive hazards.
2. Never fly near an echo with a radar top above 30,000 feet.
3. Circumnavigate all echoes with a steep or asymmetrical gradient.
4. Assume that all 50 dbz echoes are severe thunderstorms.

The Absolute Radar Rule

Never, positively **ever**, continue flight toward a radar shadow.

Objective Storm Hazards Indexing Test

Convective weather is a highly dynamic phenomenon, often exploding from benign shower to severe thunderstorm in as little as three or four minutes. No presently available, or contemplated, airborne radar can accurately predict when such an explosion is imminent. Therefore, each pilot, in each situation, must make a judgement.

To assist you in making a correct judgment, we offer the following index. After identifying an area of precipitation near your projected flight path with airborne radar, or by looking through the windshield, **whether it's contouring or not**, find answers to the following questions. The number of YES answers to questions 1 through 6 will indicate the potential for an atmospheric explosion. The number of YES answers to questions 7 through 10 will indicate what your circumnavigation distance should be.

Is It a Hazardous Storm?

1. Is the local atmosphere significantly unstable?
2. Is the dewpoint greater than 10°C?
3. Is the temperature/dewpoint spread greater than 17°C?
4. Is its speed of movement greater than 10 knots?
5. Is there visible evidence of a hazard?
6. Is it the southernmost cell in a line?

How Hazardous is it?

7. Is its height greater than 15,000 feet?
8. Is its gradient and shape asymmetrical?
9. Is its reflectivity greater than 50 dBz?
10. Is it casting a shadow?

NOTE: This Index is for the North American continent and a surface temperature of 80°F or greater. Other geographic locations may require an altered set of questions.

Radar Performance Tests

Pre-departure:
To insure that mechanical as well as electrical portions of your radar system are functioning prior to takeoff, follow these procedures:

A. Test the system as instructed in your operating handbook.

B. After departing the ramp, select full up-tilt, a weather mode and your shortest displayed range.

C. Work tilt down in increments until an echo is seen on the display.

> **Caution:** Never test a radar where personnel are within the forward 100-foot arc of your aircraft. Never test a radar when a highly reflective object is within 100 yards of that forward arc.

D. Return the tilt to full up.

> **NOTE:** To be certain your radar is, in fact, functional, you must see an echo on the display when an operating mode is selected.

Enroute:
The above test insures that the system is functioning. Next you must test for a minimum acceptable performance level as follows:

A. After takeoff, select a weather mode, the next available range greater than 100 nm and –1° tilt.

B. Above 10,000 feet AGL, check the display to insure that you are seeing ground objects to at least 100 nm throughout the swept sector. At 5,000 feet, ground objects should appear to at least 70 nm.

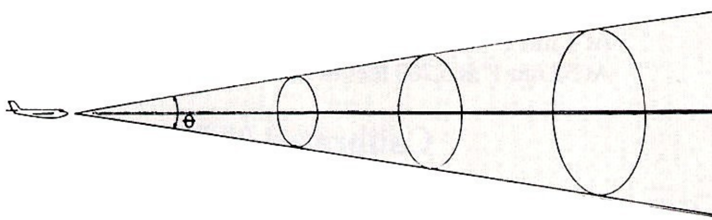
C. Conduct the test frequently and establish a "normal" range to ground echoes. If at a future time that range becomes less, radar performance has degraded.

D. If that degradation is seen on a clear day, consult maintenance.

E. If degradation of performance is noted in weather (when the radome is wet or has ice on it), allow for attenuation when analyzing echo strengths. As a guideline, if weather attenuation is noted, assume all echoes are at least one level more reflective than depicted.

Tilt Management

Radar Beam



Beam Width

Assuming a round antenna dish, either parabolic or flat plate, the radar beam is conical with a width in degrees as indicated:

Antenna Size	X-Band	C-Band
10 inch	10°	NA
12 inch	8°	NA
18 inch	5°	NA
24 inch	4°	6.5°
28 inch	3.5°	6°
30 inch	3°	5°

Beam widths are approximate to within the accuracy of the tilt mechanism itself.

Note: If a truncated rather than a round antenna is installed, the beam shape will be oval or a fan rather than conical. The above relationship will be true, with the vertical dimension of the beam in degrees coinciding with the vertical measurement of the antenna in inches and the horizontal dimension of the beam coinciding with the horizontal measurement of the antenna. Example: Assuming X-band radar, an antenna 12 inches vertically by 18 inches horizontally will produce a fan beam 8° high in the vertical plane and 5° wide in the horizontal plane. In the special case of antennas installed in the leading edge of a wing, the beam is fan shaped; about 22° vertically and 8° horizontally.

The Width of a Degree

To calculate the width of a degree, use the ancient rule of 60:

NM X 100 = Feet per Degree — at that distance

Examples:
At 1 nm 1° is 100 feet in width.
At 52 nm 1° is 5,200 feet in width.

Calibrated 0° Tilt

Calibrated 0° tilt is the tilt selection that results in the **center** of the beam being parallel to the earth. It is not necessarily at the 0° position on the tilt indicator. It may be quickly determined by consulting the following charts.

Finding Calibrated 0° Tilt
Low Level
(X-Band)

Adjust bottom of beam to sweep ground at the 10 nm range, then raise/lower tilt as indicated. You have now selected calibrated 0° tilt.

Altitude	Antenna Size/Beam Width					
AGL	10"/10°	12"/8°	18"/5°	24"/4°	28"/3.5°	30"/3°
2,000	−3°	−2°	−0.5°	0°	+0.5°	+0.5°
4,000	−1°	0°	+1.5°	+2°	+2.5°	+2.5°
6,000	+1°	+2°	+3.5°	+4°	+4.5°	+4.5°
8,000	+3°	+4°	+5.5°	+6°	+6.5°	+6.5°
10,000	+5°	+6°	+7.5°	+8°	+8.5°	+8.5°

NOTE: For C-band radar with a 28" or 30" antenna, use the 18"/5° column in each of the above tables.

CAUTION: All beam width and calibration charts in this Pilot's Operating Guide assume that the gain control is in the calibrated position and that a weather mode is selected. On some radars the beam shape changes when MAP is selected. On many radars the system calibration changes in MAP.

Finding Calibrated 0° Tilt
Mid Level
(X-Band)

Adjust bottom of beam to sweep ground at the 20 nm range, then raise tilt as indicated. You have now selected calibrated 0° tilt.

Altitude	Antenna Size/Beam Width					
AGL	10"/10°	12"/8°	18"/5°	24"/4°	28"/3.5°	30"/3°
12,000	+1°	+2°	+3.5°	+4°	+4.5°	+4.5°
14,000	+2°	+3°	+4.5°	+5°	+5.5°	+5.5°
16,000	+3°	+4°	+5.5°	+6°	+6.5°	+6.5°
18,000	+4°	+5°	+6.5°	+7°	+7.5°	+7.5°
20,000	+5°	+6°	+7.5°	+8°	+8.5°	+8.5°
22,000	+6°	+7°	+8.5°	+9°	+9.5°	+9.5°

Finding Calibrated 0° Tilt
High Level
(X-Band)

Adjust bottom of beam to sweep ground at the 40 nm range, then raise tilt as indicated. You have now selected calibrated 0° tilt.

Altitude	Antenna Size/Beam Width					
AGL	10"/10°	12"/8°	18"/5°	24"/4°	28"/3.5°	30"/3°
25,000	+1.5°	+2.5°	+4°	+4.5°	+5°	+5°
27,000	+2°	+3°	+4.5°	+5°	+5.5°	+5.5°
29,000	+2.5°	+3.5°	+5°	+5.5°	+6°	+6°
31,000	+3°	+4°	+5.5°	+6°	+6.5°	+6.5°
33,000	+3.5°	+4.5°	+6°	+6.5°	+7°	+7°
35,000	+4°	+5°	+6.5°	+7°	+7.5°	+7.5°
37,000	+4.5°	+5.5°	+7°	+7.5°	+8°	+8°
39,000	+5°	+6°	+7.5°	+8°	+8.5°	+8.5°
41,000	+5.5°	+6.5°	+8°	+8.5°	+9°	+9°

A More Accurate Method For Finding Calibrated 0°

Calibration of the tilt indicator using the preceding charts will result in acceptable accuracy, provided the radar system is properly calibrated electrically and provided the procedure is conducted over "radar-soft" terrain such as level farm land or a forested area.

A more accurate method, which cancels out electrical miscalibration of the radar system and terrain effects, is conducted as follows:

A. In stable, level flight over flat terrain, select a normal weather mode and turn antenna stabilization off, if possible.

B. Determine your altitude AGL in thousands of feet, to the nearest 1,000 feet, and double it. The result is "The Range."

Examples:
At 6,000 feet AGL, "The Range" is 12 nm.
At 17,000 feet AGL, "The Range" is 34 nm.
At 38,000 feet AGL, "The Range" is 76 nm.

C. Adjust tilt so ground is being painted outward from a number of miles corresponding to your altitude as determined in "B" and note the tilt indication.

Examples:
At 6,000 feet AGL, ground should appear from 12 nm out.
At 38,000 feet AGL, ground should appear from 76 nm out.

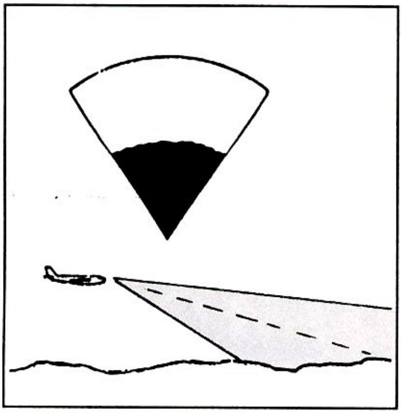
D. After noting the tilt indication in "C", lower tilt until **no** ground is painted outward from the distance used in "C" (put the top of your beam on "The Range") and again note the tilt indication.

E. The difference in tilt indications "C" and "D" is your beam width.

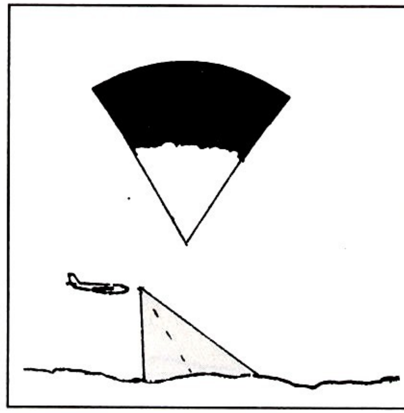
F. Add 5° to one-half the difference between tilt indications "C" and "D".

G. Increase tilt from "D" by the number of degrees calculated in "F".

H. The center of your beam is now level with the plane of the earth and the indicated tilt is calibrated 0° for your antenna installation.



Tilt at "C".



Tilt at "D".

The above procedure may be used to confirm proper mechanical and electrical calibration of the entire radar system.

- If calibrated 0° tilt is more than 1° from the 0° mark, up or down, the antenna is misaligned to the aircraft. Have the antenna base plate shimmed or the stabilization aligned, as required.

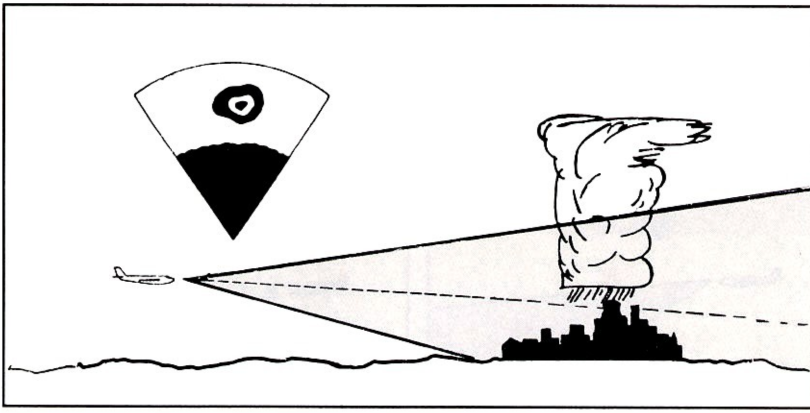
- If the difference between tilt indications "C" and "D" is less than the theoretical beam width for your antenna diameter (see page 3), your receiver sensitivity is probably set too low. Have the system bench checked.

- If the difference between tilt indications "C" and "D" is more than 4° greater than the theoretical beam width, your receiver sensitivity is probably set too high. Again, a bench check is suggested.

- If the difference between tilt indications "C" and "D" equals your theoretical beam width when the calibration procedure is conducted at altitudes above 20,000 feet AGL, but is more than 4° greater than the theoretical beam width at altitudes of 15,000 feet AGL and lower, your STC may be out of calibration. Consult your radar technician.

- If calibrated 0° changes when the procedure is repeated with antenna stabilization turned on and then turned off, your stabilization system is misaligned. Have it adjusted.

The Parked Configuration



Any time you aren't actively, hands-on operating the radar system, tilt and range should be in the normal, or PARKED, configuration.

The PARKED configuration gives you a fast and certain means to insure the radar is functioning, is the ideal ground mapping configuration, provides for a cross check on altimetry in the terminal area, relieves you from adjusting tilt at frequent intervals and – most important – insures that you will instantly recognize radar shadows.

The PARKED configuration is selected as follows:

A. Select TIP. (See page 12.)

B. Lower tilt 4° from TIP.

C. Tilt is now at the Normal Antenna Position, or NAP.

D. If operating at 15,000 feet AGL or below, adjust the displayed range so ground is being painted on the outer one-third to one-half of the indicator.

E. If above 15,000 feet AGL, select the 100 nm range.

With tilt and range in the PARKED configuration, monitor the indicator at frequent intervals for the following:

A. At 15,000 feet AGL or below:

- If the indicator suddenly goes blank, your radar just failed.

- If black areas grow from the outer edge of the indicator inward, you are approaching a radar shadow.

- Any prominent echo that works back inside ground returns is most likely weather.

- An echo that works back to the 5 nm arc will be cleared by **less than** 2,000 feet, **if it is cleared at all!**

- An echo that cannot be identified by town, city, mountain peak or other known geographic feature, is a weather system.

- An echo that changes rapidly in size, shape or intensity is a dynamic weather system.

- If your assumed position does not correlate to the radar map, you have a navigation system error.

- In unaccelerated flight, if your radar and altimeters disagree, resolve the conflict. Your altitude AGL should be the distance to the inner edge of ground returns times 400 as follows:

Distance	5 nm	10 nm	15 nm	20 nm	30 nm	50 nm
Altitude AGL	2,000	4,000	6,000	8,000	12,000	20,000

B. When operating above 15,000 feet AGL:

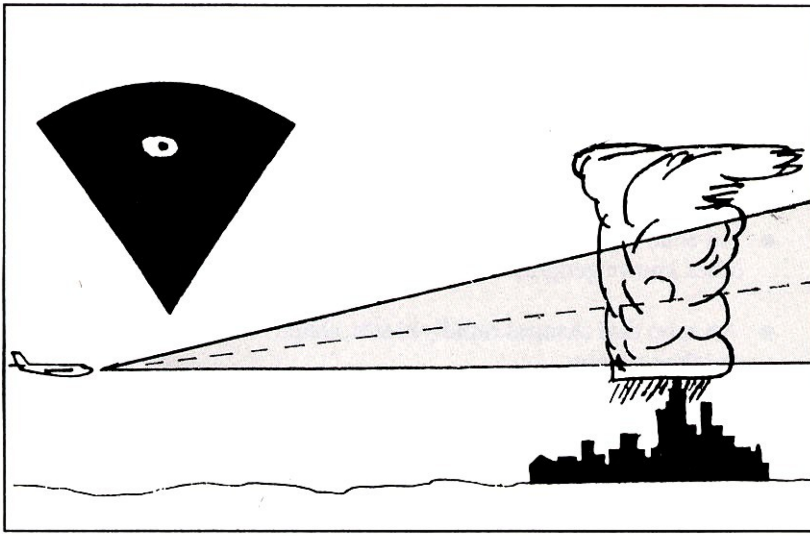
- Any echo that intrudes inside the 50 nm arc is probably weather.

- Any echo that intrudes inside the 30 nm arc is weather that will be cleared by **less than** 12,000 feet, **if at all!** Immediately begin a deviation.

NOTE: When operating with a 12-inch or smaller antenna above FL290, a PARKED tilt position of –2° from calibrated zero is recommended. The advice to deviate around all echoes inside the 30 nm arc will remain valid.

CAUTION: Above 15,000 feet, occasionally lower the tilt until ground is painted for several sweeps to insure that your radar is still functioning.

TIP – Threat Identification Position



This tilt selection results in the **bottom** of your beam being parallel to the earth directly below you. When TIP is selected, all echoes depicted (except for side lobe returns) are from objects that intrude through your current altitude. TIP is one-half a beam width above calibrated 0° tilt.

Alternately, TIP may be quickly selected as follows:

A. Determine your altitude AGL in thousands of feet, to the nearest 1,000 feet.

B. Adjust tilt so ground is being painted outward from a number of miles corresponding to your altitude as determined in "A".

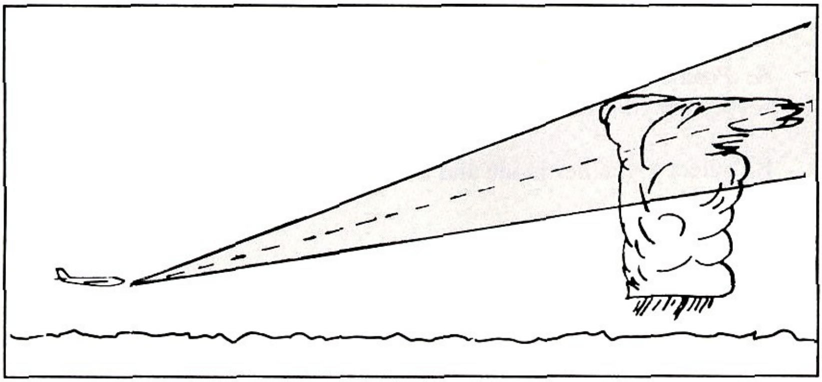
C. Raise tilt 10° from position "B".

D. The bottom of your beam is now parallel to the earth directly below you.

NOTE: Calibrated 0° tilt is one-half a beam width down from TIP.

CAUTION: Tilt must not be left at TIP or TUT for more than a half dozen sweeps. **Always** return tilt and the selected range to the PARKED configuration before moving on to other cockpit duties.

TUT – Tilt-Up Technique



TUT is the tilt setting that results in the **center** of the beam pointing up 10° with respect to the earth. In short, it is calibrated 0° plus 10°.

Alternately, TUT may be selected as follows:

A. Select TIP.

B. Lower tilt from TIP one-half your beam width.

C. Increase tilt 10° from position B.

D. Tilt is now at TUT.

TUT should be used frequently when operating below 15,000 feet as an aid to recognizing tall, hazardous weather and to prevent inadvertently flying into the hazardous area below a storm with a high base. With tilt at TUT, the **minimum** radar top of any object depicted on your display, or the **minimum** height of the contour within a weather system, is in the ratio 1,000 to 1, as follows:

Distance	10 nm	20 nm	30 nm	40 nm	50 nm
Height	10,000 ft.	20,000 ft.	30,000 ft.	40,000 ft.	50,000 ft.

With tilt at TUT in the terminal area, it is recommended that you:

- Circumnavigate all contouring echoes.
- Circumnavigate all echoes, whether contouring or not, displayed at a range of 20 nm or greater.

Estimating Radar Tops

Before departure:

A. Position the aircraft so the expected departure route is within the scan of your radar.

B. Select a weather mode and a range of 40 or 50 nm.

C. Select 15° of up-tilt.

D. Detected weather has a **minimum** radar top relative to distance as follows:

Distance	10 nm	15 nm	20 nm	30 nm	40 nm
Min. Height	15,000 ft.	22,500 ft.	30,000 ft.	45,000 ft.	60,000 ft.

E. Lower tilt to +10° and select the 100 nm or next greater range.

F. The distance/minimum height is now:

Distance	15 nm	20 nm	30 nm	40 nm	50 nm	60 nm
Min. Height	15,000 ft.	20,000 ft.	30,000 ft.	40,000 ft.	50,000 ft.	60,000 ft.

G. Lower tilt to +5°, range on 100 nm or the next greater range.

H. The distance/minimum height is now:

Distance	30 nm	40 nm	50 nm	60 nm	80 nm	90 nm
Min. Height	15,000 ft.	20,000 ft.	25,000 ft.	30,000 ft.	40,000 ft.	45,000 ft.

Enroute:

First select TIP. All echoes depicted are returns from objects with a **minimum** height equal to your current altitude AGL. To determine how much taller:

A. Increase tilt from TIP until the echo of interest just disappears.

B. The radar top relative to your current altitude is **Distance X 100 X tilt change from TIP.**

Example:
An echo at 37 nm disappears with a tilt increase of 4° from TIP.
37 X 100 X 4 = 14,800 feet

The weather system has a radar top approximately 15,000 feet above your current altitude.

Note: More important than the current radar top is the trend. A growing storm should always be avoided by a greater distance than a static or dissipating one.

CAUTION: When operating above 20,000 feet, frequently return tilt and range to the PARKED configuration to insure that you do not fly into a storm with a **radar top** lower than your present altitude.

Arrival:

Frequently select TUT. With the center of your beam angled up 10°, radar tops relative to your current altitude, have this relationship to distance:

Distance	10 nm	20 nm	30 nm	40 nm	50 nm
Height	10,000ft.	20,000 ft.	30,000 ft.	40,000 ft.	50,000 ft.

CAUTION: Radar top is not the storm height. For over-flight planning, assume the actual storm top is 20% above the radar top.

Antenna Stabilization

Today most radar antenna systems are stabilized in reference to the surface of the earth. This means simply that the center of the beam sweeps parallel to the horizon at the tilt angle selected on the tilt control, regardless of the roll and pitch attitude of the aircraft.

You must be alert, however, to the several limitations and imperfections in the stabilization system.

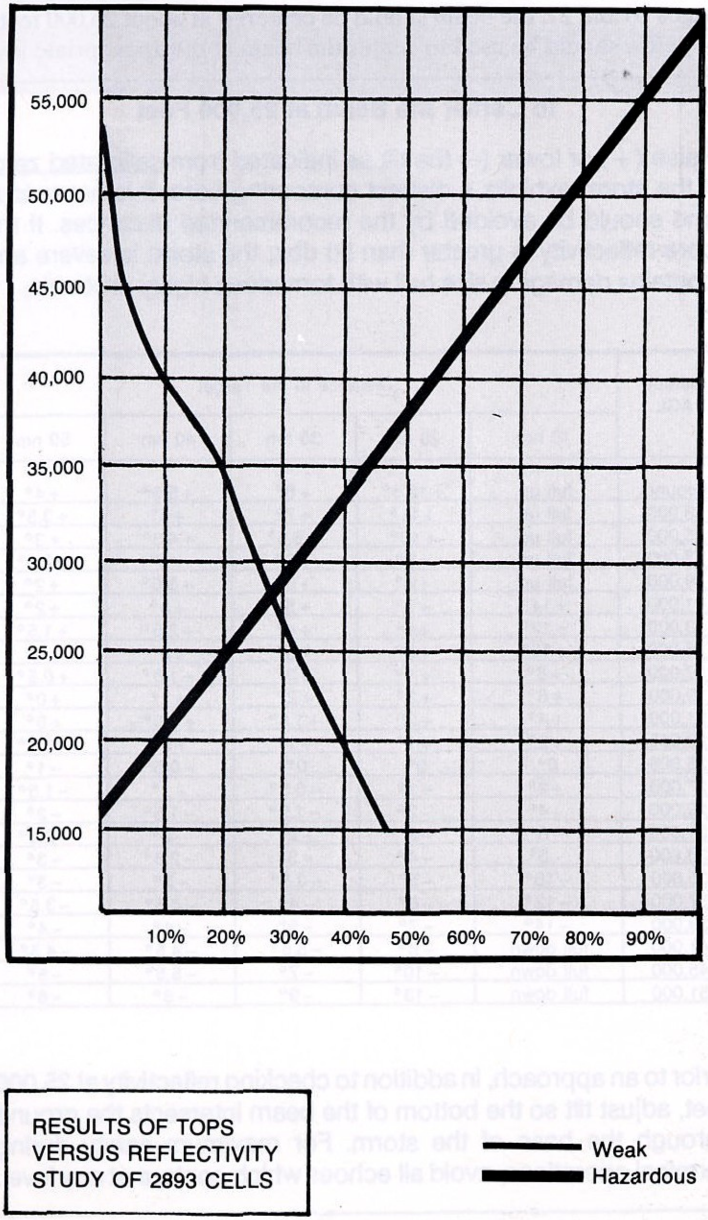
- The limits of stabilization vary with antenna design. They range from 25° to 43°. You should know what they are for your antenna. That information will be found in the pilot's operating handbook for your radar system.

- The limits of antenna stabilization is the **sum of**—tilt selection from the 0° index, plus pitch and roll attitude from level flight. In the pitch axis, that summation is not the normal arithmetical addition. In pitch, a plus and a minus are added, but a plus and a plus, or a minus and a minus, must be subtracted, the smaller number from the larger.

- In most aircraft the vertical reference for antenna stabilization is a mechanical gyro. Mechanical gyros are subject to acceleration, deceleration and turning errors due to precession. Gyro precession often exceeds 5°. Therefore, antenna stabilization will be imperfect during and following maneuvers. Gyro precession errors will cancel out after two to five minutes of stable, unaccelerated flight.

- Since maneuvering causes gyro precession, the calibrated 0° position on the tilt control will change appreciably following takeoff and during approaches. This requires recalibration of the tilt indicator at frequent intervals during terminal maneuvers.

Tops Versus Storm Intensity



Tilt Positions for Measuring Reflectivity

To use reflectivity as a measure of the probability of turbulence and/or hail, as indicated by the curves in the Turbulence and Hail Size Probability charts on pages 26 and 27, the beam should be centered at about 25,000 feet. The chart below should be used to center the beam at the appropriate level.

To Center the Beam at 25,000 Feet

Raise (+) or lower (–) the tilt as indicated from calibrated zero. If the storm exhibits a distinct contouring core, it is hazardous and should be avoided by the recommended distances. If the core reflectivity is greater than 50 dbz, the storm is severe and contains damaging size hail with tornadoes highly probable.

Altitude AGL	Distance to the Target				
	10 nm	20 nm	30 nm	40 nm	50 nm
Ground	full up	+12.5°	+8°	+5.5°	+4°
3,000	full up	+11°	+7°	+5°	+3.5°
5,000	full up	+10°	+6.5°	+4.5°	+3°
7,000	full up	+9°	+6°	+4°	+2.5°
9,000	full up	+8°	+5°	+3.5°	+2°
11,000	+14°	+7°	+5°	+3°	+2°
13,000	+12°	+6°	+4°	+2.5°	+1.5°
15,000	+10°	+5°	+3°	+2°	+1°
17,000	+8°	+4°	+3°	+1.5°	+0.5°
19,000	+6°	+3°	+2°	+1°	+0°
21,000	+4°	+2°	+1.5°	+0.5°	+0°
23,000	+2°	+1°	+1°	+0°	−0.5°
25,000	0°	0°	0°	−0.5°	−1°
27,000	−2°	−1°	−0.5°	−1°	−1.5°
29,000	−4°	−2°	−1.5°	−1.5°	−2°
31,000	−6°	−3°	−2°	−2°	−2.5°
33,000	−8°	−4°	−3°	−2.5°	−3°
35,000	−10°	−5°	−3.5°	−3°	−3°
37,000	−12°	−6°	−4°	−3.5°	−3.5°
39,000	−14°	−7°	−5°	−4°	−4°
41,000	full down	−8°	−5.5°	−4.5°	−4.5°
45,000	full down	−10°	−7°	−5.5°	−5°
51,000	full down	−13°	−9°	−8°	−6°

Prior to an approach, in addition to checking reflectivity at 25,000 feet, adjust tilt so the bottom of the beam intersects the ground through the base of the storm. For maximum safety during terminal operations, avoid all echoes which contour at any level.

NWS versus Airborne Radar Intensity Levels

The "levels" depicted on airborne radar can be very misleading when compared to the "VIP levels" used by the National Weather Service.

Most airborne radars today symbolize only three ranges of reflectivity. But note in the chart that what is called "Level 3" on airborne radar may in fact be an NWS Level 3, Level 4, Level 5 or Level 6 in echo intensity.

Further complicating the interpretation of airborne radar, an NWS Level 3 weather system may be simply smooth stratiform rain. This explains why a pilot often flies into a "Level 3" echo as depicted on airborne radar and gets a wet but smooth ride. At other times a "Level 3" echo on airborne radar may in fact be an extreme thunderstorm.

Therefore, "levels" alone are poor indications of hazard on airborne radar. You must use some form of Hazard Index, plus airborne radar measurements of height, gradient and ultimate intensity, to supplement the basic symbology seen on your radar display.

NOTE: Some higher cost radars incorporate "Level 4" symbology. But it's not "Level 4" at all, it's actually NWS Levels 5 and 6.

<table>
<tr><th colspan="4">Intensity Levels and Descriptions</th></tr>
<tr><th>Reflectivity</th><th>NWS</th><th>Most Airborne Radars</th><th>Select Airborne Radars</th></tr>
<tr><td>57 dbz & greater</td><td>Level 6-Extreme</td><td rowspan="4">Level 3-Hazardous
(red)</td><td rowspan="2">Level 4-Very Hazardous
(magenta)</td></tr>
<tr><td>50-56 dbz</td><td>Level 5-Intense</td></tr>
<tr><td>47-49 dbz</td><td>Level 4-Very strong</td><td rowspan="2">Level 3-Hazardous
(red)</td></tr>
<tr><td>41-46 dbz</td><td>Level 3-Strong</td></tr>
<tr><td>30-40 dbz</td><td>Level 2-Moderate</td><td>Level 2-Moderate
(yellow)</td><td>Level 2-Moderate
(yellow)</td></tr>
<tr><td>MDS-30 dbz</td><td>Level 1-Weak</td><td>Level 1-Weak
(green)</td><td>Level 1-Weak
(green)</td></tr>
</table>

On the other hand NWS VIP levels, as determined with NWS ground radars, should never be overlooked as a prime source of information. NWS Level 3 and Level 4 echoes are serious weather. NWS Level 5 and Level 6 echoes are severe storms and should be avoided by a distance of at least 10 nm.

Using Gain to Identify 50 dbz Storms

All echoes with a reflectivity of 50 dbz or greater should be considered severe thunderstorms. Avoid carefully, particularly on the upwind flank.

All VIP Level 5 and 6 echoes, as reported by NWS, are 50 dbz weather systems. Many newer airborne radars identify 50 dbz echoes with a magenta fourth color. Operators of radars that indicate only three intensities can also identify 50 dbz echoes with the GAIN control.

If your radar has click stops on the GAIN knob, turn it counterclockwise two clicks from MAX (or from MAP on some Bendix systems with a monochrome display). If the "contour" symbology (a black hole, the third intensity of light or red) is still displayed, the echo strength is 50 dbz or greater. Avoid by at least 10 nm.

If your radar does not have click stops on the GAIN, follow this procedure:

A. With GAIN at the calibrated position, note the size of the "contour." ("Contour" is the black hole, the third intensity of light or red, depending on indicator type.)

B. Take GAIN out of "calibrated" and adjust so the overall size of the **entire** echo is reduced to the size of the "contouring" portion that was noted in A.

C. If the echo still "contours," it is a 50 dbz severe weather system. Avoid as recommended on page 29.

NOTE: With an analog display, first insure that it remains in "contour" mode with the GAIN out of "calibrated."

NOTE: On some radar systems, notably the newer Collins designs, you will find it impossible to reduce gain and thus reduce the size of the echo.

CAUTION: Do not reduce GAIN if your radome is wet or iced over, or if the echo is behind another echo. In those situations **all** contouring echoes must be considered severe. **Always** return GAIN to "calibrated" immediately after each use.

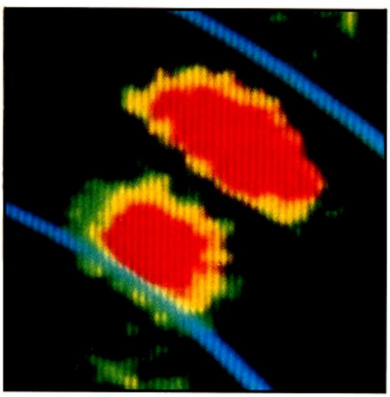
Storm Shapes

When used with other clues in combination, the shapes of precipitation, as presented on your radar display, are helpful in gauging the potential for hazard presented by an echo. The telltale shapes are often fleeting, however. One may appear at a certain tilt setting but at no other. And often a revealing detail will disappear after a single sweep.

So failure to spot a particular shape or feature does not mean the weather is necessarily non-hazardous.

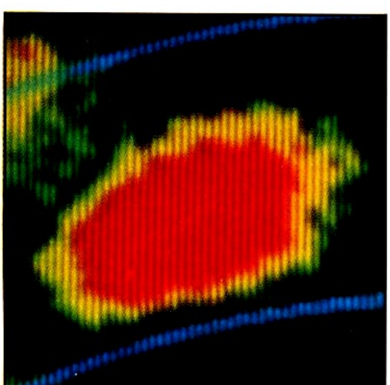
Also, keep in mind that overall size of the echo is not a valid measure of hazard potential. A small echo may be more hazardous than a neighboring large one.

Otherwise, shapes, when viewed in the context of atmospheric instability, radar tops, movement, reflectivity and through-the-windshield clues, are a valuable input when assessing the hazard potential of an area of precipitation.



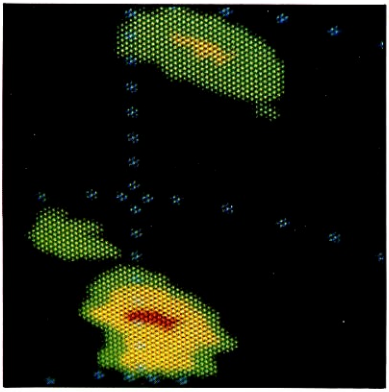
Round or oval

Convective showers and general thunderstorms tend to produce a round or oval echo on airborne radar. A convective shower or general thunderstorm should never be penetrated, but either can be approached to within a mile or two without undue risk. The more the shape deviates from round or oval, the greater should be your circumnavigation distance.

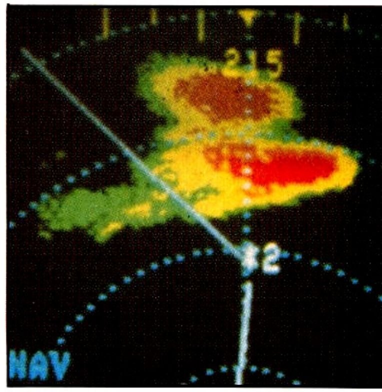


Steep gradient

The rain gradient depicted in an echo is an indication of vertical shear potential. Gradient is the distance from the outer edge of the echo to the contour, black hole, the third level echo strength or red symbology. The steeper the gradient, the greater the potential for extreme shears, both vertical and — near the ground — horizontal.



Shallow gradient

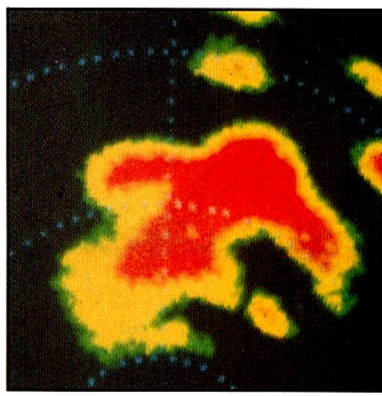


Asymmetrical gradient

Be especially wary of storms with a lopsided or asymmetrical gradient.

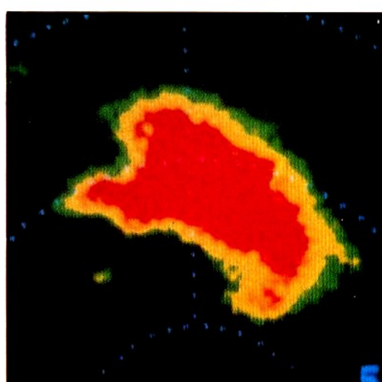
Notches, fingers, hooks

A notch, either U-shaped or a V, indicates extreme vertical shear. Fingers are a characteristic of hail producing storms. If a finger appears to curl into a loop, suspect a tornado. Be especially cautious of an echo with a large hook protruding from the southwest edge.

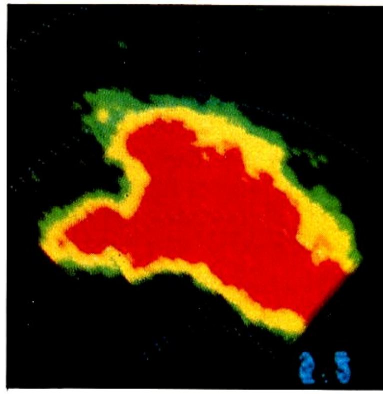


Pendant shape

Pendant shaped echoes should be avoided by a wide distance. Most major tornado-producing storms have had this shape. Typically, they are oriented with the large end northeast, the small end southwest. A notch in the large end indicates a strong wind aloft from the small end towards the large end. Movement is normally toward the notched end. Variations of the pendant shape are spearpoint, heart or frying pan appearing echoes.



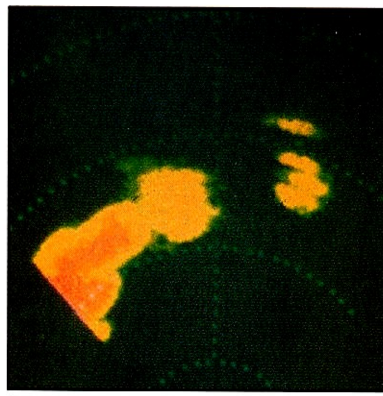
Scalloped edges



A wavy, scalloped edge on the echo is typical of a hail producing storm. Square turns in the gradient indicate extreme activity.

Protrusions, fingers and hooks on the far side of the contour, pointing toward your radar antenna, suggest the presence of extreme hail shafts.

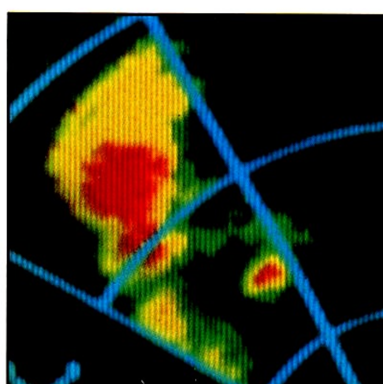
Dissipating and building echoes



An indistinct, fuzzy appearance along the outer periphery of an echo, as in the echo on the left, is a clue that the storm has passed through the mature stage and has begun to dissipate. It may still be extremely dangerous, but if you will be patient, it will soon dissipate into a non-hazardous area of heavy rain.

The hard, crisp look of the echoes on the right is the characteristic appearance of growing storms. Growing storms can be expected to last for 45 minutes or more. In that period one or more may explode to a height of 40,000 feet or greater at a rate in excess of 6,000 feet per minute. Be very cautious about over-flying any short but hard appearing echo.

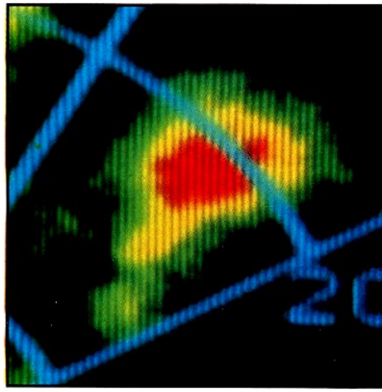
Mae West

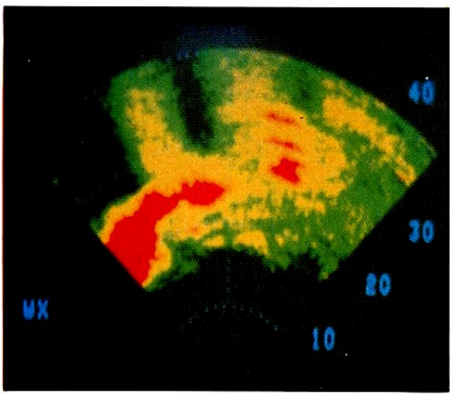


Echoes with the Mae West, or hour-glass, shape should be carefully avoided. In a bicellular complex, one cell will frequently become dominant, sucking in the energy and moisture of the weaker cell. The result can be an atmospheric explosion producing severe microbursts, surface gusts above 70 knots and extreme rain. The entire event may occur in as little as five minutes.

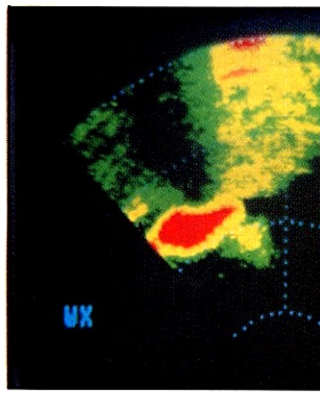
Frying-pan

The frying-pan shaped echo is a variation of the pendant shaped severe storm. Expect hail, extreme gusts and possibly a tornado in or near the frying pan shape.





Shadow

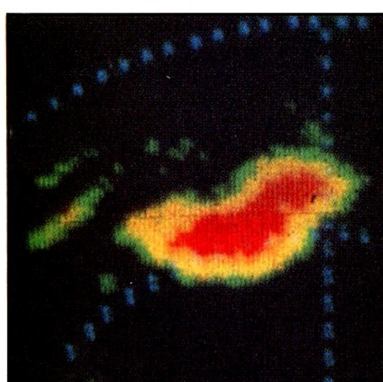


Shadow

The absolute, never, never rule in using airborne radar is you must positively avoid radar shadows. Aloft they are easily identified by simply selecting an appropriate range then adjusting antenna tilt down to a position that should result in ground returns being painted on the outer one-third of the indicator. Radar shadows are the black areas at the outer extremity of the displayed range.

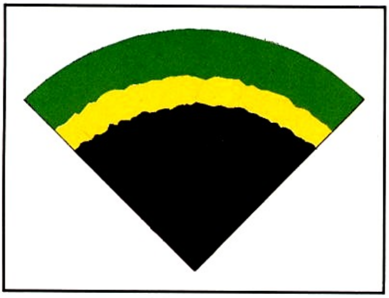
Crescent shape

On the ground, scan the storm at +5°, +10° and +15° tilt. If a bowed echo, arcing opposite to the arc of the range marks is displayed, it is a shadow-producing, severe thunderstorm. Another indication is a dip towards you on the back, or far, side of the echo.

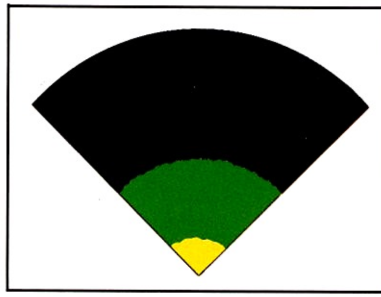


Light/Moderate Rain Attenuation

When flying in light to moderate stratus rain, or when the radome is iced over, you may encounter attenuation of radar energy which reduces range performance to as little as one or two miles. To check for this condition, select tilt and range to the PARKED configuration.



Normal



Attenuated

If the inner portion of the display is full of returns and the outer portion is black, severe attenuation is occurring. Extreme storms may not be detected and displayed with a contour before actual penetration.

When this condition is identified, immediately take the following actions:

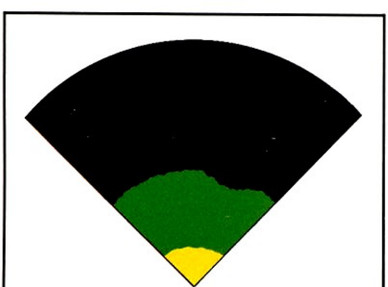
1. Inform ATC and request vectors around all precip detected by ATC radar.

2. If your radar transmitter power output is 5,000 Watts or less, try progressively greater range selections.

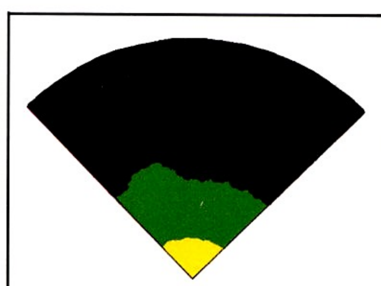
3. Occasionally select full up tilt for four sweeps; any echo detected in the outer distance is a hazardous storm.

NOTE: Return tilt to the PARKED position after the four sweeps.

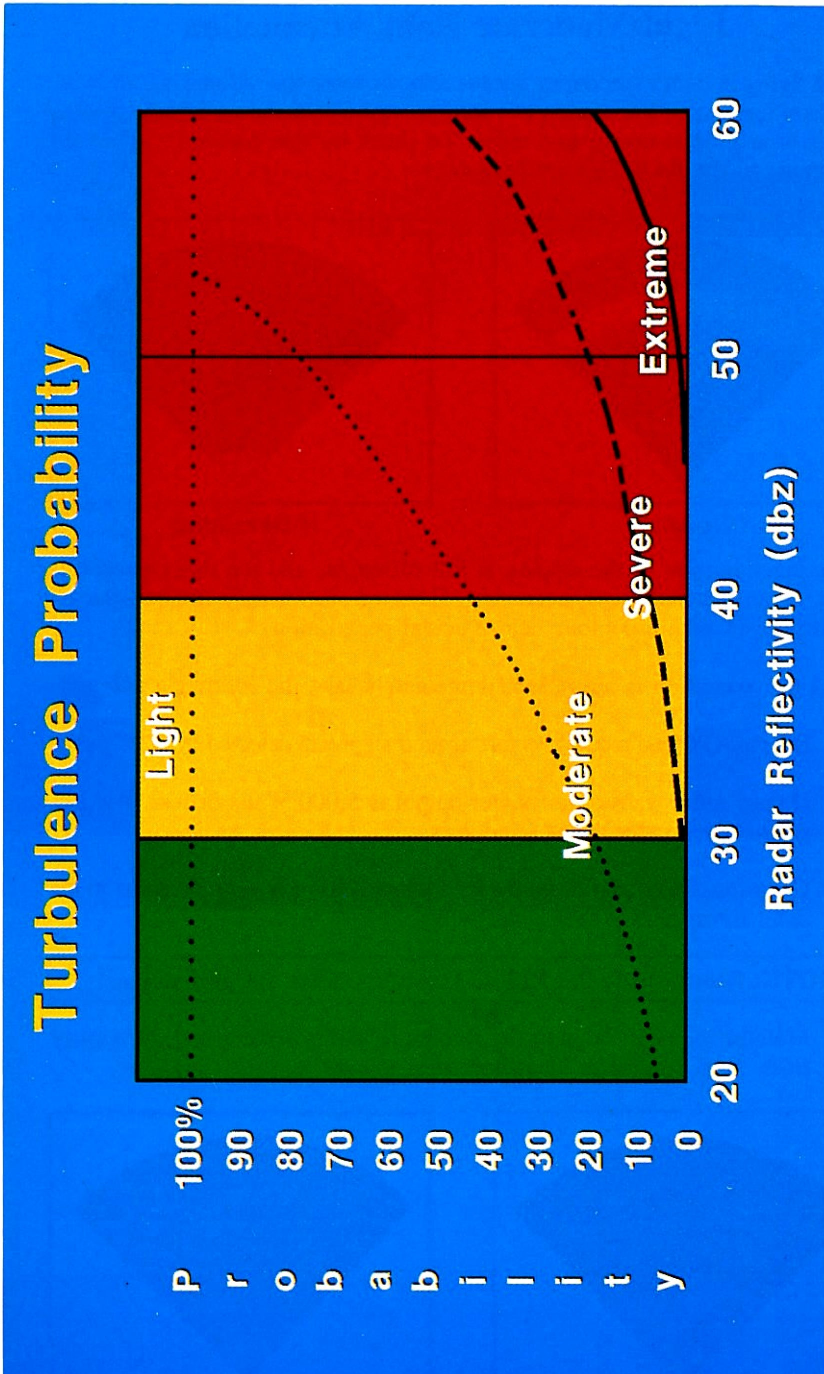
4. Monitor the outer edge of the returns. If a dip is identified, turn away from it. If a bulge is identified, turn toward it.

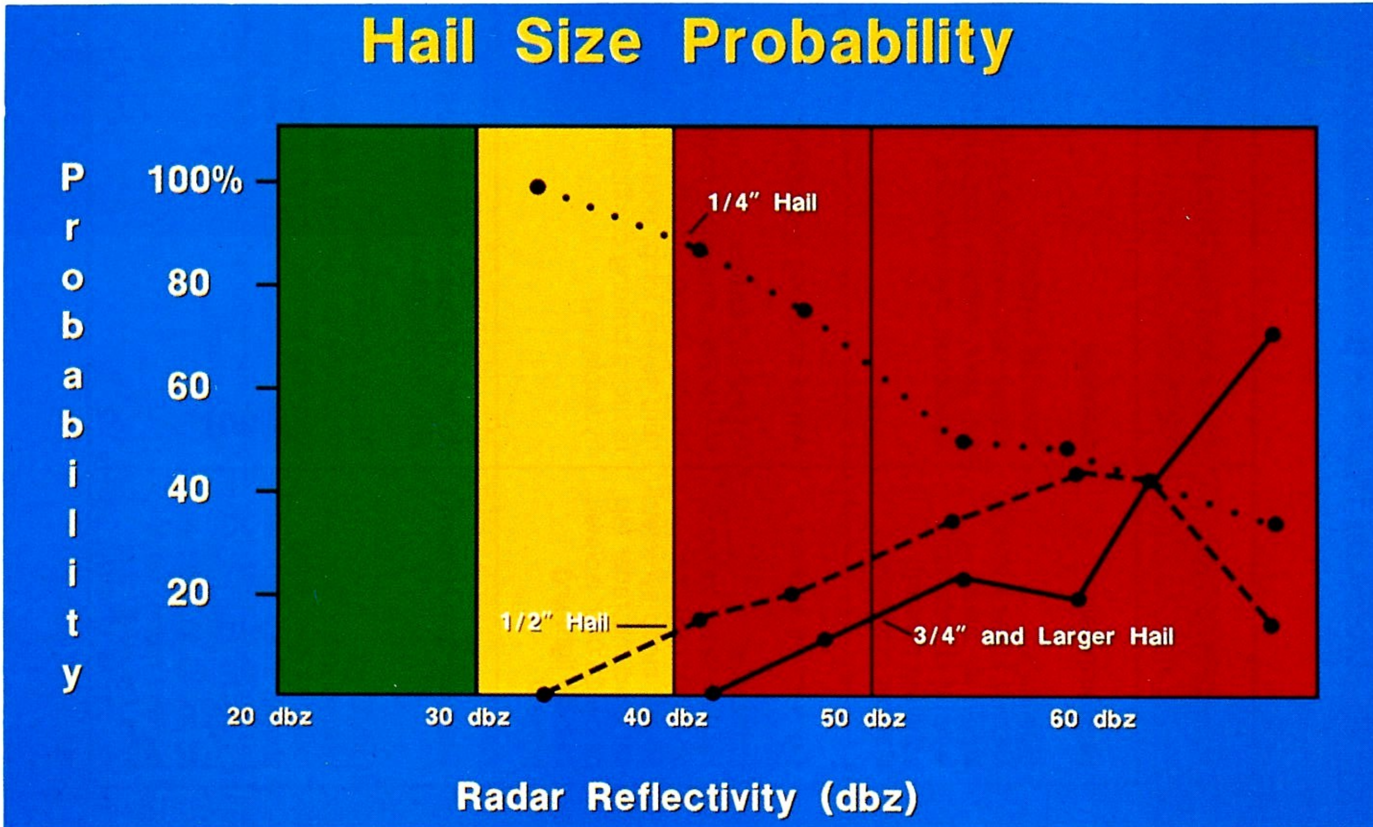


Dip



Bulge


Turbulence Probability
Probability
100%
90
80
70
60
50
40
30
20
10
0
20
30
40
50
60
Radar Reflectivity (dbz)
Light
Moderate
Severe
Extreme


Hail Size Probability
Probability
100%
80
60
40
20
1/4" Hail
1/2" Hail
3/4" and Larger Hail
20 dbz
30 dbz
40 dbz
50 dbz
60 dbz
Radar Reflectivity (dbz)

Avoidance Distance Recommendations

Precipitation Type	Recommended Circumnavigation Distances
Statiform rain Indicators: Hazard Index below 2; stable air mass; layered clouds; no lightning present; shallow gradients	**Optional** Potential hazards: Heavy rain; moderate to severe clear ice; poor visibility; reduced braking coefficient; hydroplaning
Convective shower Indicators: Hazard Index below 3; round or oval echo shape; steep symmetrical gradient; radar top below 25,000; isolated cell; no lightning present	**Avoid crossing a gradient** Potential hazards: Moderate turbulence; occasional severe bumps; strong surface gusts; heavy rain; severe icing; poor visibility; reduced braking coefficient; hydroplaning
General thunderstorm Indicators: Hazard Index 5 or less; round or oval echo shape; steep symmetrical gradient; lightning present; radar tops 25,000 to 30,000 feet; isolated storm; reflectivity below 50 dbz	**Avoid all detectable precipitation and visible cloud** Potential hazards: Moderate and severe turbulence; lightning strikes; severe icing; gusts to 50 knots; heavy rain in sheets; poor visibility; reduced braking coefficient; hydroplaning

Precipitation Type	Recommended Circumnavigation Distances
Severe thunderstorm	**Below freezing level** — Avoid all detectable precipitation by at least 10 nm in the south and west quadrants, 20 nm north and east quadrants. Avoid flight below all visible portions of the storm especially south and west. **Above freezing level** — Avoid all detectable precipitation by at least 20 nm, all quadrants. Avoid all visible cloud by at least 5 nm **Overflight** — Radar top +20% **OAT +5°C to −15°C** — Avoid continuous operation at these altitudes
Indicators: Hazard Index 3 or above; pendant shape; asymmetrical gradient; notches, fingers, hooks, scalloped edges; radar top above 30,000 feet; southernmost cell in a line; movement above 20 knots; reflectivity above 50 dbz; NWS echo strength of Level 5 or 6; prominent shadow	Potential hazards: Severe and extreme turbulence; large hail; severe icing; tornadoes; lightning strikes; microbursts; gusts in excess of 50 knots; extreme rain; engine failures; loss of lift; zero visibility; severe hydroplaning
NOTE: Not all indicators will necessarily be present in every general or severe thunderstorm.	**NOTE:** Although a general or severe thunderstorm may have a well defined base, hazards often exist to ground level, including VMC beneath the base.

Recommended Radar Operating Practices

1. Ground map frequently on VMC days.

2. Leave the radar on with an operating mode selected throughout the leg if it will be needed on any portion of the leg.

3. Exercise the magnetron 12 months of the year.

4. Return tilt and range to the PARKED configuration after each use.

5. Inspect the radome before each flight.

6. With a monochrome display, do not, positively do not, select **contour** for more than six sweeps.

Avoidance Guidelines

- Assume that all weather with a radar top above 15,000 feet may be hazardous.

- Assume that all weather with a radar top above 20,000 feet **is** hazardous.

- Assume that all weather with a radar top above 30,000 feet is very hazardous.

- Assume that all weather with a reflectivity above 50 dbz is extremely hazardous.

- **Never** assume that ATC will warn you of hazardous weather.

- **Never** assume you will receive a PIREP, even when the weather is extreme.

The Radar Rule

Remember, the one hard and fast radar rule is

NEVER, never fly into a radar shadow.

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