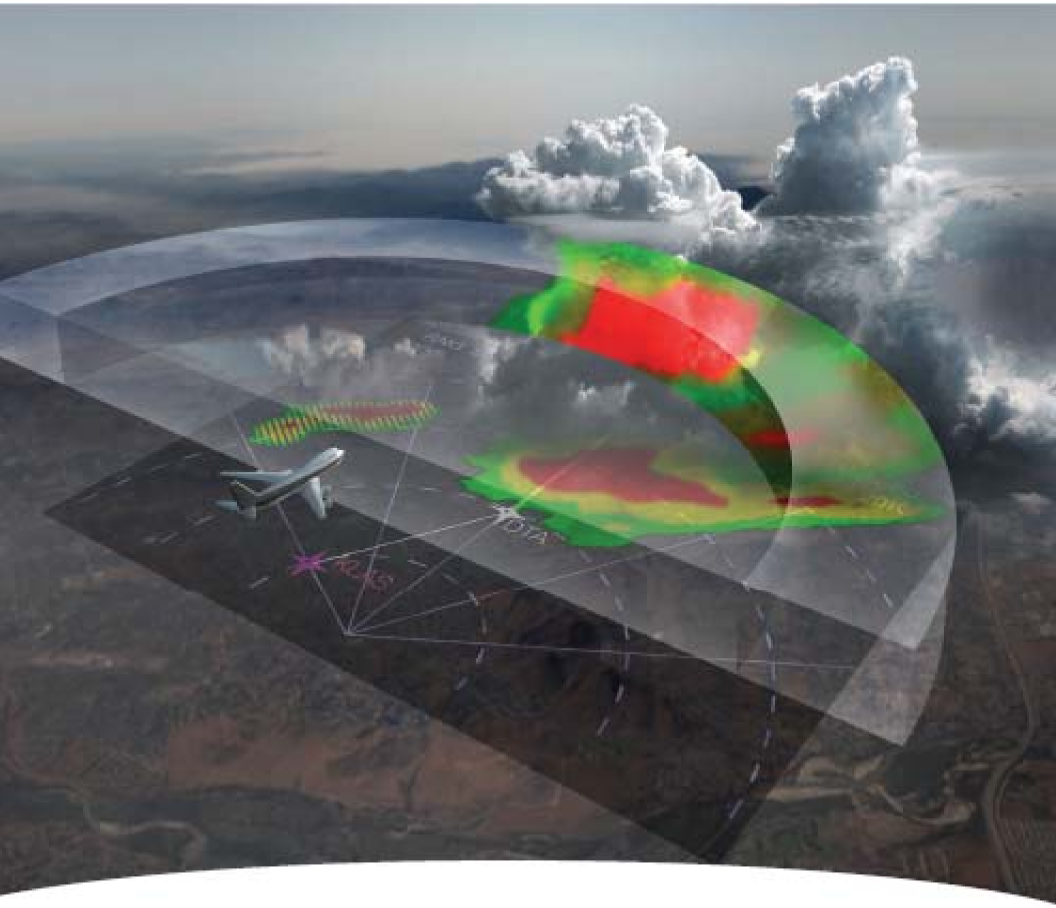
Honeywell

IntuVue™ RDR-4000



IntuVue 3-D Automatic Weather Radar System with Forward Looking Windshear Detection

For Airbus SA/LR Aircraft

Pilot's Guide

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TABLE OF CONTENTS

SECTION 1: INTRODUCTION

Welcome to Honeywell's IntuVue 3-D Automatic Weather Radar System, model RDR-4000. The RDR-4000 introduces several new technologies not found in previous generation Radar Systems. Some of the major operational differences are highlighted here. Note that the availability of some features will depend on the installation configuration.

RDR-4000 OPERATIONAL ENHANCEMENTS

- Predictive Hail and Lightning Icons (if installed)
  - Areas ahead of the aircraft that have a high probability of producing hail or lightning are indicated by the display of appropriate icons.
- REACT (Rain Echo Attenuation Compensation Technique) (if installed)
  - Indicates areas where attenuation of the radar signal is severe enough to degrade the ability to display weather behind significant intervening weather.
- Automatic control of antenna tilt for reduced pilot workload
  - No traditional tilt control.
- 3D (Three-Dimensional) Volumetric Memory
  - The entire sky in front of aircraft is automatically scanned (out to 320 nautical miles (nm) and from ground to 60,000 feet (ft)).
  - All weather information is stored and continuously updated.

  - Automatically corrects for curvature of the earth.
  - Pilots can choose among display options as desired.
- Internal Topography Database
  - Used to remove ground clutter from weather displays and to remove weather returns from the MAP display.
- More sensitive weather detection for more accurate weather depiction
  - Improved long-range performance.
  - 3D scanning detects more weather close to the aircraft as compared to other weather radar systems.
- Differentiation of weather in and out of path of the aircraft
  - In ALL or ALL WX mode, weather that is far above or below the aircraft's flight path (**Off Path**) is displayed in a different pattern than **On Path** weather.
  - In ON PATH or PATH WX mode, the display of weather that is **Off Path** is suppressed. Only the weather that is relevant to the flight path is shown.
  - In ELEVN mode, view horizontal slices through the weather in 1,000-foot increments, from ground level to 60,000 ft.
- Weather/Turbulence Ahead Alerting
  - Alerts the pilot when significant weather or turbulence is detected on the flight path trajectory.
- Map mode for identification of terrain features
  - Use MAP mode for identifying prominent terrain features, such as coastlines, lakes, and large built-up urban areas.

The RDR-4000 is a technically advanced system, but as always, there are physical limitations to consider.

- The use of a topography database results in a significant reduction in ground returns. However, the database is not aware of man-made reflectors such as buildings at airports and cities. Therefore, it is possible that not all ground clutter will be eliminated.
- The antenna beam is very narrow at close ranges and widens significantly with range. Therefore, the resolution and accuracy of weather reflectivity is better at ranges closer to the aircraft.

OPERATIONAL LIMITATIONS AND CONSIDERATIONS

The limitations of the radar system have been consolidated here because of their importance. This section should be read thoroughly and frequently as a reminder of weather radar limitations.

- Weather detection, analysis, and avoidance are the primary functions of the radar system. Airborne weather systems are not intended as a terrain or traffic collision avoidance system.
- Your radar is a weather avoidance tool. It should never be used for weather penetration. It will help you see and plan avoidance maneuvers around significant weather encountered during flight.
- Radar detects raindrops, hail, and ice particles. It does not detect clouds or fog.
- Radars detect the presence of precipitation. Storm associated turbulence without precipitation can extend several thousand ft above a storm and outward more than 20 nm.
- Turbulence detection requires the presence of precipitation. Clear-air turbulence is not detected or displayed.
- The weather display corresponds to the selected range while the turbulence display is overlaid for the first 40 nm in the ALL and ON PATH modes (regardless of range selected). If the Hazard Display features are installed, turbulence will be displayed for the first 60 nm, and will be shown in the ALL WX, PATH WX, and ELEVN modes.
- Hail and lightning icons indicate that conditions are conducive to the development of hail or lightning. Since this technology is predictive, icons often appear prior to the actual formation of the hail or lightning. Hence, the presence of icons does not guarantee that hail or lightning will be present. Similarly, the absence of an icon does not guarantee that the condition will not be present.
- Below 1,800 ft windshear and weather scans are interleaved. The windshear detection operation is transparent to the crew unless an alert is issued.
- Leave the system OFF until it is safe to operate the radar (see *ON/OFF* on page 6). While OFF there is no radiation hazard to nearby personnel.
- Reference the following Federal Aviation Administration (FAA) Advisory Circulars:
  AC 00-24B Thunderstorms
  AC 00-6A Aviation Weather
  AC 00-50A Low Level Wind Shear
  AC 20-68B Recommended Radiation Safety Precautions

SECTION 2: SIMPLIFIED OPERATING PROCEDURES

CONFIGURATIONS

Your system may have one of two control panels. The control panel installed indicates which features are available on your system.

		
Modes	OFF, ALL, ON PATH, ELEVN, MAP	OFF, ALL WX, PATH WX, ELEVN, MAP
Turbulence Detection	First 40 nm ALL and ON PATH modes	First 60 nm ALL WX, PATH WX, and ELEVN modes
Hazard Detection	Not available	First 160 nm ALL WX, PATH WX, and ELEVN modes
REACT	Not available	Provided in ALL WX, PATH WX, and ELEVN modes
WX/Turb Ahead Alerting	Not available	Alerts provided when turbulence or hazardous weather exists ahead of the aircraft

ON/OFF

The radar may be turned completely off by selecting OFF with the System Control Switch, which is located in the top center of the control panel. When this switch is in the OFF position, no weather radar information is available, and no predictive windshear detection will occur. This switch should always be set to ON (System 1 or System 2 selected) whenever it is safe to operate the radar. This will ensure that the radar is always scanning while in flight so that the most current weather information is instantly available in the 3D memory.

The Radar is **OFF** (**Not Transmitting)** when:

- The System Control Switch on the Radar control panel is set to OFF
- **Or** the System Control Switch on the Radar control panel is set to either System 1 or System 2, **and**
  - The aircraft is on the ground and the PWS Qualifiers are not satisfied (See *AUTOMATIC WINDSHEAR ACTIVATION* on pg 18)
  - **And** the Display Selection Knobs for both the CAPT and F/O are set to OFF

The Radar is **ON (Transmitting)** when:

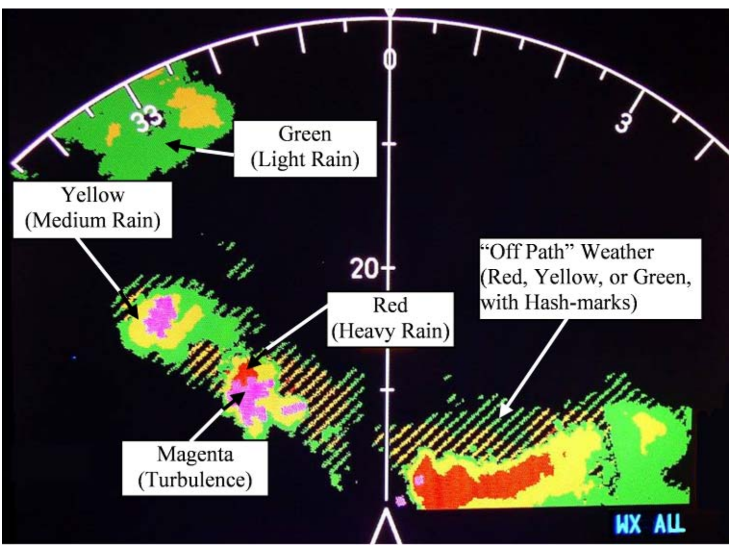
- The System Control Switch on the Radar control panel is set to either System 1 or System 2, **and**
  - The aircraft is on the ground and at least one (CAPT or F/O) Display Selection Knob is set to any radar mode except OFF
  - **Or** the aircraft is on the ground and the PWS Qualifiers are satisfied (See *AUTOMATIC WINDSHEAR ACTIVATION* on pg 18)
  - **Or** the aircraft is in the air

Radar data is shown on the display when:

- The System Control Switch on the Radar control panel is set to either System 1 or System 2, **and**
  - The Display Selection Knob is set to any radar mode except OFF
  - **Or** there is a PWS Alert (See *AUTOMATIC WINDSHEAR ACTIVATION* on page 18)

TAKEOFF AND DEPARTURE

- System Control: 1 or 2 (dual system) or 1 (single system)
- Turb Switch: AUTO or Turb Pushbutton: Engaged
- HZD Pushbutton (if provided): Engaged
- Mode: ALL/ALL WX or ON PATH / PATH WX
- Gain: AUTO or as required to assess threats. (Refer to *GAIN CONTROL* on page 25 for more details.)
- Range: Pilot Flying – 10 to 40 nm, other side at least one range higher.
- Avoid any magenta turbulence cells and monitor the display for weather intensity to avoid any weather threats.
- Avoid any cells associated with Hail or Lightning Icons (see page 15).
- In areas where the REACT field is shown, expect the possibility of weather that may need to be avoided (see page 16).
- If there is weather in the area, ensure that the radar has been turned on in time to allow pilot(s) to evaluate any threats prior to takeoff.
- See *PLANNING A PATH* on page 40 for more information.



CLIMB UP TO FL200

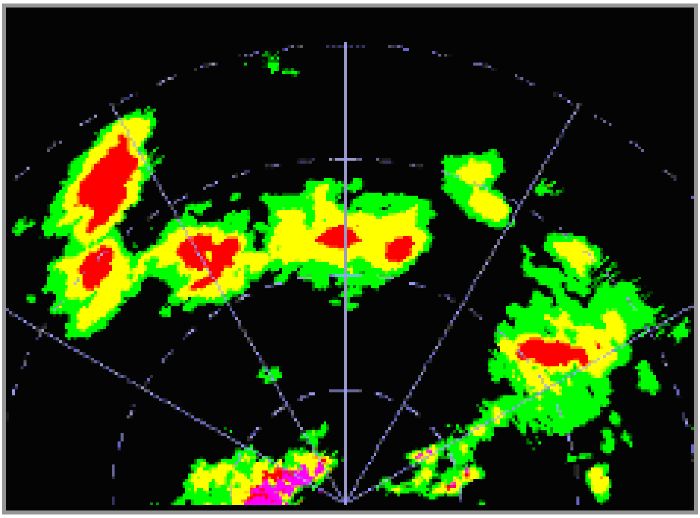
- System Control: 1 or 2 (dual system) or 1 (single system)
- Turb Switch: AUTO or Turb Pushbutton: Engaged
- HZD Pushbutton (if provided): Engaged
- Mode: ALL/ALL WX or ON PATH/ PATH WX
- Gain: AUTO or as required to assess threats. (Refer to *GAIN CONTROL* on page 25 for more details.)
- Range: Pilot Flying – 10 to 40 nm, other side at least one range higher
- Avoid any magenta turbulence cells and monitor the display for weather intensity to avoid any weather threats.
- Avoid any cells associated with Hail or Lightning Icons (see page 15).
- In areas where the REACT field is shown, expect the possibility of weather that may need to be avoided (see page 16).
- See *PLANNING A PATH* on page 40 for more information.

CRUISE ABOVE FL200

- System Control: 1 or 2 (dual system) or 1 (single system)
- Turb Switch: AUTO or Turb Pushbutton: Engaged
- HZD Pushbutton (if provided): Engaged
- Mode: ALL/ALL WX or ON PATH/ PATH WX
- Gain: AUTO or as required to assess threats. (Refer to *GAIN CONTROL* on page 25 for more details.)
- Range: Pilot Flying – 20 to 80 nm, other side at least one range higher.
- Within 60 nm sufficient resolution exists for evaluating cells. At this point On Path and Off Path weather will become more prominent and ELEVN mode can be used for vertical analysis.
- Avoid any magenta turbulence cells and monitor the display for weather intensity to avoid any weather threats.
- Avoid any cells associated with Hail or Lightning Icons (see page 15).
- In areas where the REACT field is shown, expect the possibility of weather that may need to be avoided (see page 16).
- See *PLANNING A PATH* on page 40 for more information.

DESCENT AND APPROACH

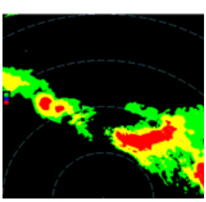
- System Control: 1 or 2 (dual system) or 1 (single system)
- Turb Switch: AUTO or Turb Pushbutton: Engaged
- HZD Pushbutton (if provided): Engaged
- Mode: ALL/ALL WX or ON PATH/ PATH WX
- Gain: AUTO or as required to assess threats. (Refer to *GAIN CONTROL* on page 25 for more details.)
- Range: Pilot Flying – 10 to 40 nm, other side at least one range higher.
- Avoid any magenta turbulence cells and monitor the display for weather intensity to avoid any weather threats.
- Avoid any cells associated with Hail or Lightning Icons (see page 15).
- In areas where the REACT field is shown, expect the possibility of weather that may need to be avoided (see page 16).
- Start evaluating cells by 40 nm and finish by 20 nm.
- Make your weather decision by the 20 nm point.
- See *PLANNING A PATH* on page 40 for more information.



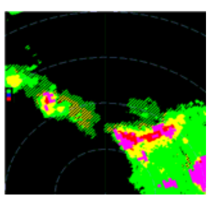
AVOIDANCE MANEUVERS

When considering avoidance maneuvers keep the following in mind:

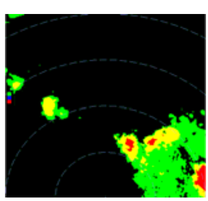
- Never deviate under a storm cell or the associated anvil.
- Plan deviations on the upwind side of storm cells to avoid turbulence generated downwind of convection, which may not be detectable by the radar.
- When flying between storm cells allow at least 40 nm separation.
- Damaging hail can be thrown at least 20 nm from the storm cell by upper level winds.
- Avoid all yellow, red, or magenta areas, particularly if they can be associated with convective activity.
- Avoid any cells associated with Hail or Lightning Icons by a minimum of 20 nm (see page 15).
- In areas where the REACT field is shown, expect the possibility of weather that may need to be avoided (see page 16).
- Establish an avoidance plan before getting within 40 nm of the cells to allow time to negotiate a deviation with ATC. (See *PLANNING A PATH* on page 40 for more information).
- Consider the height of a storm cell when planning avoidance.
  - o Avoid all green, yellow, red, and magenta areas of cells taller than 28,000 ft by at least 20 nm.
  - o Cells exceeding 35,000 ft should be considered extremely hazardous and additional separation (in addition to the 20 nm) should be used.



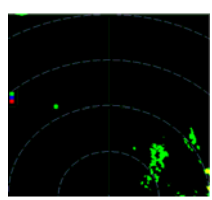
**ELEVN MODE:
SLICE AT 10,000 FT
(10,000 FT BELOW A/C)**



"ALL" or "ALL WX"



**ELEVN MODE:
SLICE AT 20.000 FT
(e.g. AT A/C ALTITUDE)**



**ELEVN MODE:
SLICE AT 30,000 FT
(10,000 FT ABOVE A/C)**

SECTION 3: EXPANDED OPERATING INSTRUCTIONS

TURN ON & SYSTEM SELECTION

For single radar systems (only one radar processing system), place the System Control Switch in the **1** position to put the system into weather mode.

For dual radar systems (two independent radar processing systems) place the System Control Switch in either the **1** or **2** position to select the system to be used. To ensure that both systems are used alternate between systems on successive flights.

Radar data is then displayed whenever the Display Selection Knob is set to any radar mode except OFF. When on the ground, the radar will not transmit if both (CAPT and F/O) Display Selection Knobs are set to OFF, unless the PWS qualifiers are active (see *AUTOMATIC WINDSHEAR ACTIVATION* on pg 18). When in the air the radar scans continuously, always updating the memory so that current weather is immediately available. (See also *ON/OFF* on page 6.)

On initial activation of the radar, or when switched from one system to the other (**1** or **2**), the radar first looks at the part of the sky that is near the aircraft's altitude. This data is displayed as soon as it is available. As data is gathered from the remainder of the sky in front of the aircraft, the display quickly fills in with any additional information. It takes no more than 30 seconds for the complete picture to become available. Note that when switching from one system to the other, the weather depicted may not exactly match what was previously displayed due to the loss of "historical" data from the other system. Therefore, there is no advantage in switching between systems during flight, except in the case of the failure of one side.

WEATHER DETECTION

AUTOMATIC WEATHER MODE (ALL/ALL WX or ON PATH/ PATH WX)

GENERAL DESCRIPTION

The ALL/ALL WX and ON PATH/ PATH WX modes provide weather, turbulence, and predictive windshear detection. The system processes the data to fill the 3D memory and extracts the selected data for display. When a PWS event is detected, an icon is shown on the display. Returns determined to be ground clutter are not shown.

Weather targets are color-coded by the intensity of the return. The display correlation to approximate rainfall (with Gain set to AUTO) is as follows:

Reflectivity Color Codes (Gain at AUTO)

Color	Returns	Reflectivity	Rainfall Rate
Black	Very light or none	Less than 20 dBZ	Less than 0.7 mm/hr (0.028 in/hr)
Green	Light	20 – 30 dBZ	0.7 – 4 mm/hr (0.028 – 0.16 in/hr)
Yellow	Medium	30 – 40 dBZ	4 – 12 mm/hr (0.16 – 0.47 in/hr)
Red	Strong	40 dBZ or greater	Greater than 12 mm/hr (0.47 in/hr)
Magenta	Turbulence	N/A	N/A

ON PATH/ PATH WX WEATHER

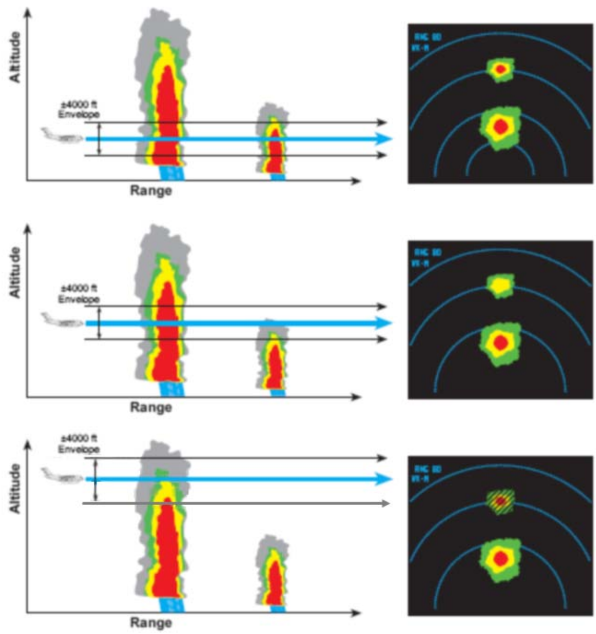
The RDR-4000 fills the 3D memory with all the detected weather in front of the aircraft out to 320 nm, and from ground level up to 60,000 ft mean sea level (MSL). The RDR-4000 displays weather along the flight path (designated **flight path** weather) using solid colors. All other weather is designated as **off path** weather. When in the ON PATH/ PATH WX mode, only the **on path** weather is displayed.

The nominal flight path weather envelope is ±4,000 ft with respect to the expected flight path. At cruise altitudes above 29,000 ft MSL, the floor of the envelope is extended down to 25,000 ft MSL when necessary to ensure that relevant convective activity is displayed. On the ground and during departure or approach, the ceiling of the envelope is fixed at 10,000 ft MSL. This provides approximately 10 minutes of look-ahead.

ALL/ ALL WX WEATHER

Select the ALL/ALL WX mode to display both **on path** and **off path** weather. The **off path** weather is displayed with black stripes through it. (See diagram on page 34.)

This mode is useful for situational awareness and to aid in making changes to your flight plan to avoid **on path** weather. See the following examples to visualize the displayed weather.



UNDERSTANDING THE DISPLAY IN ALL/ALL WX AND ON PATH/ PATH WX MODES

In ALL/ALL WX or ON PATH/ PATH WX mode, the RDR-4000 projects a three dimensional memory space onto a two dimensional display. This means the weather displayed for any one memory cell is the color of the strongest return in that column of memory cells. Specifically, if there is any weather data in a given column that is inside the envelope for **on path** weather; the color of the strongest of these returns is displayed. If there is no weather data inside the envelope, then the color of the strongest return from outside the envelope is displayed as **off path** weather.

Stronger returns outside the envelope (**off path** weather) never override the returns displayed as **on path** weather.

TURBULENCE DETECTION

Turbulence detection is an automatic function of this weather radar system.

For turbulence detection and evaluation use the following procedure:

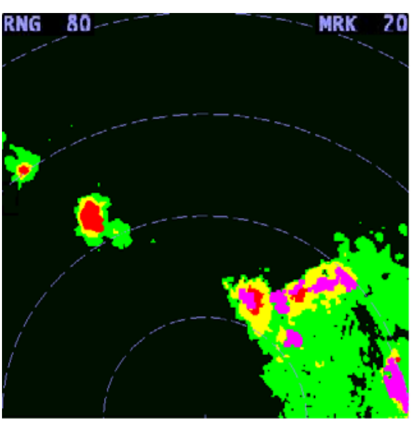
1. System Control: 1 or 2 (dual system) or 1 (single system)
2. Turb Switch: AUTO or Turb Pushbutton: Engaged
3. Mode: ALL/ALL WX or ON PATH/ PATH WX
4. Range: As desired

Turbulence information is limited to the first 40 nm (60 nm if the Hazard Display Configuration is installed). Turbulence within this range and inside the turbulence envelope will be displayed in magenta.

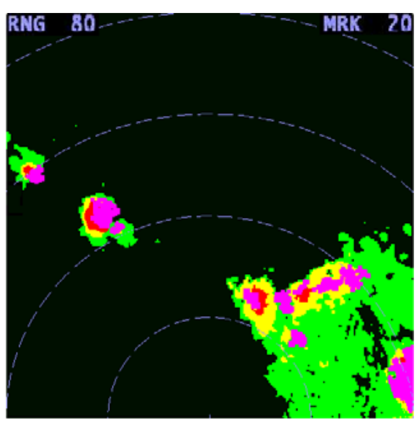
The turbulence data is represented in a **blocky** shape, helping to visually differentiate it from reflectivity data. If required, the display of turbulence information may be turned off by setting the Turbulence Select Switch to OFF, or by disengaging the Turbulence Pushbutton.

The turbulence detection feature of the RDR-4000 is quite sensitive as compared to previous radar functionality. The threshold for displaying indications of turbulence is based on the potential aircraft response to that turbulence. Therefore, magenta blocks may be displayed on top of any color, including black.

TYPICAL TURBULENCE DISPLAY



Limited to 40 nm



Extended to 60 nm

PREDICTIVE HAIL AND LIGHTNING (Hazard Display Feature)

If the Hazard Display Configuration of the radar system is installed, icons will be displayed on top of the reflectivity to identify areas that have the signature characteristics of hail, lightning, or both.

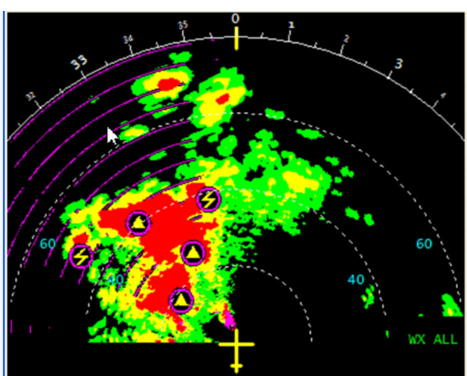
For hazard display use the following procedure:

1. System Control: 1 or 2 (dual system) or 1 (single system)
2. HZD Pushbutton: Engaged
3. Mode: ALL/ALL WX or ON PATH/ PATH WX
4. Range: As desired.

The radar does not directly detect hail or lightning; it analyzes the data in the 3D memory to identify areas that have a high probability of containing these hazards.

Hail and lightning icons indicate that conditions in the associated weather cell are conducive to the development of hail or lightning. They do not guarantee that hail or lightning will be present, nor does the absence of an icon guarantee that the condition will not be present. Note that an icon cannot indicate the exact location of any expected hail or lightning. Treat the entire weather cell or area as a threat.

See *PLANNING A PATH* on page 40 for details on how to utilize the information provided by the Hail and Lightning Icons.



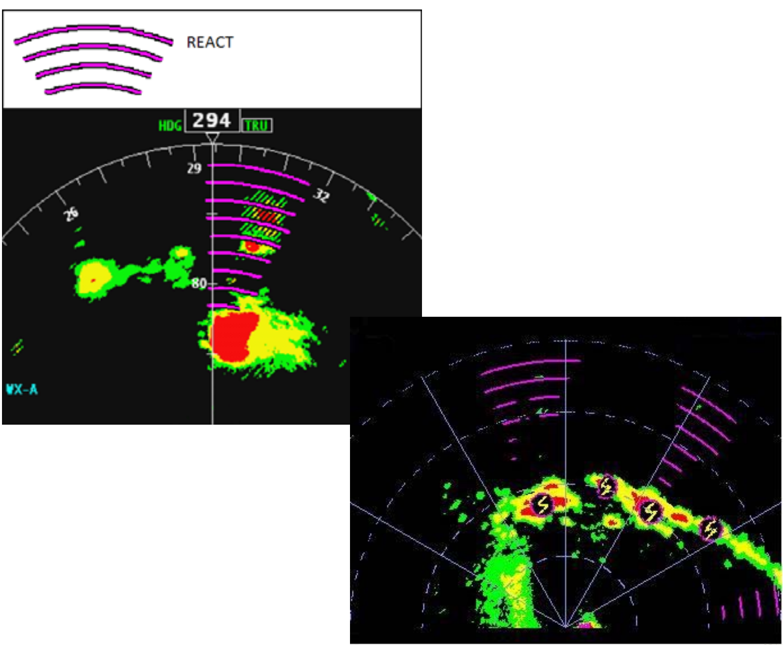
 LIGHTNING ICON  HAIL ICON

REACT (Hazard Display Feature)

REACT stands for *Rain Echo Attenuation Compensation Technique*. As the transmitted radar signal travels through heavy rain it loses power, or becomes attenuated. If this attenuation is severe enough, weather behind a storm cell may not be detectable, or it may be displayed as being less severe than it actually is (e.g., green instead of yellow).

The Hazard Display Configuration of the RDR-4000 automatically indicates areas where the radar signal has been attenuated. These areas are shown as magenta arcs superimposed over the reflectivity in the areas where the signal attenuation is significant. These arcs indicate that there could be severe weather in that area, even though only mild or no reflectivity is shown.

In areas where the REACT field is shown, expect the possibility of weather that may need to be avoided. The geometry between the aircraft and the attenuating weather may change as the flight progresses. This may allow weather that was in the REACT area to later be outside of the REACT field, and the radar will then more clearly display weather in that area.



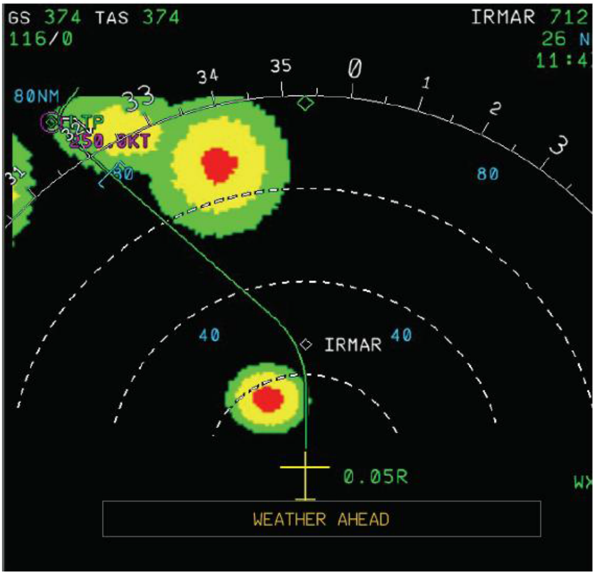
WX/TURB-AHEAD ALERTING (Hazard Display Feature)

The objective of the Weather/Turbulence Ahead alert is to let the pilot know when significant weather or turbulence is detected on the flight plan trajectory. When installed, this feature will:

- Monitor a corridor along the current flight path, and out to three minutes ahead at current aircraft speed.

The presence of turbulence or weather threats is indicated by:

- An advisory text message ("WEATHER AHEAD") on the display when the aircraft altitude is more than 1,500 ft AGL and weather or turbulence hazards are detected within the corridor.
- An aural alert ("Weather Ahead, Weather Ahead") when all of the following conditions are met:
  - o WXR is not selected for display on either side.
  - o The aircraft altitude is more than 2,500 ft AGL.
  - o The weather or turbulence hazard level changes to a higher level (e.g., no alert to weather-based alert or to turbulence-based alert).



PREDICTIVE WINDSHEAR (PWS) DETECTION

The predictive windshear feature detects the presence of windshear up to 5 nm ahead of the aircraft, giving 10 to 60 seconds of warning before the encounter. Windshear detection mode operates automatically below 1,800 ft Above Ground Level (AGL), with alerts available at 1,500 ft AGL and below. If a windshear event is detected, the system provides the crew with Advisory, Caution and/or Warning annunciations, and a windshear icon appears on the weather display. This system is meant to supplement other means of detecting and avoiding hazardous windshear conditions. It will not detect all possible hazardous windshear conditions such as extremely dry events or events masked by unusual radar clutter.

AUTOMATIC WINDSHEAR ACTIVATION

The Windshear mode will automatically be turned on under the following specific aircraft conditions:

In Air: Below 1,800 ft. AGL

On Ground: Typically oil pressure active **and** either ground speed greater than 30 kts **or** longitudinal acceleration greater than 0.15g.

If the display is showing data other than weather (such as ground proximity terrain data) when a windshear event takes place, the display automatically switches into the ALL mode, and the windshear icon is overlaid on the weather data. In this case, turbulence information is also shown, regardless of the position of the Turb Control Switch. Unless the pilot changes the display settings, the display will return to its previous state once the windshear event is no longer detected.

WINDSHEAR ALERT REGIONS

The PWS mode can generate three types of alerts; **Advisory, Caution,** and **Warning**. These depend on the location of the windshear event, not the strength. When a windshear event is encountered below 1,500 ft AGL, the appropriate alert is issued and the icon automatically appears on the display.

ADVISORY ALERTS

- The Advisory Alert region is ±40° from the aircraft track and from 0.5 nm to 5.0 nm in front of the aircraft.
- Between 50 ft and 1,500 ft AGL the system indicates ADVISORY Alerts by overlaying the windshear icon(s) on the radar display. New Advisory Alerts are inhibited below 50 ft AGL if airspeed is greater than 100 kts on takeoff, or greater than 60 kts on approach.

CAUTION ALERTS

- The Caution Alert region is ±25° from the aircraft track and from 0.5 nm to 3.0 nm in front of the aircraft.
- Between 50 ft and 1,200 ft AGL the system indicates CAUTION Alerts with visual and aural annunciations in addition to displaying the windshear icon(s). New Caution Alerts are inhibited below 50 ft AGL if airspeed is greater than 100 kts on takeoff, or greater than 60 kts on approach.

WARNING ALERTS

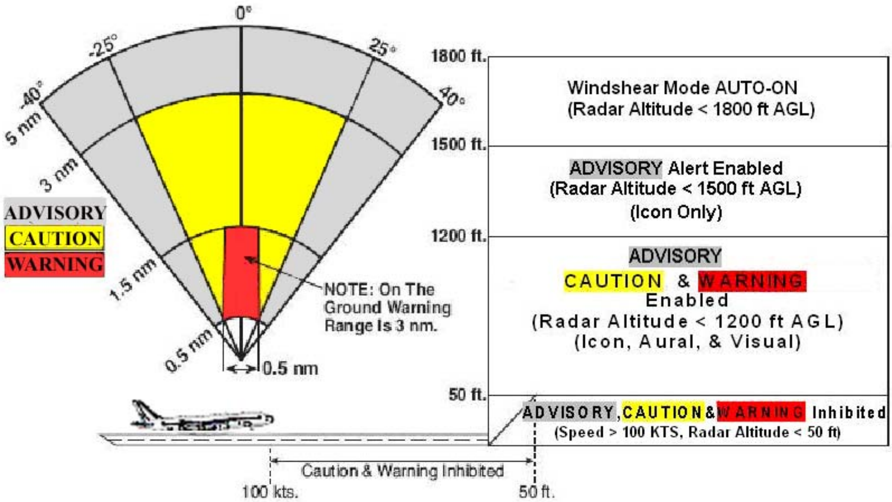
- The WARNING Alert region is ±0.25 nm either side of the aircraft track and from 0.5 nm to 1.5 nm (3.0 nm on the ground) in front of the aircraft. On approach below 370 ft, warnings beyond the far end of the runway are inhibited.
- Between 50 ft and 1,200 ft AGL the system indicates WARNING Alerts with visual and aural annunciations in addition to displaying the windshear icon(s). New Warning Alerts are inhibited below 50 ft AGL if airspeed is greater than 100 kts on takeoff, or greater than 60 kts on approach.

WINDSHEAR ALERT INHIBIT REGIONS

The following table summarizes the PWS Inhibit Regions.

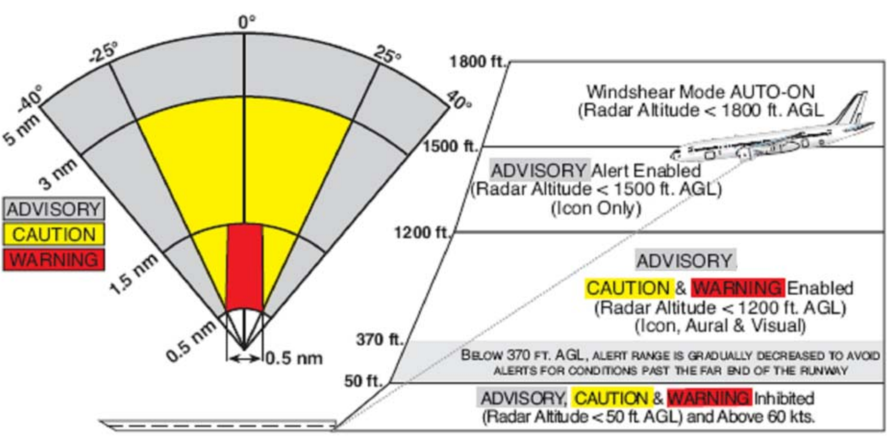
Windshear Alert Inhibit Regions
Advisory Alerts are Enabled below 1,500 ft.
Caution and Warning Alerts are Enabled below 1,200 ft.
On **Takeoff**, **All** New Alerts are INHIBITED when airspeed is greater than 100 kts if radio altitude is less than 50 ft AGL.
On **Approach**, **All** New Alerts are INHIBITED when airspeed is greater than 60 kts if radio altitude is less than 50 ft AGL.

TAKE-OFF ALERT REGIONS



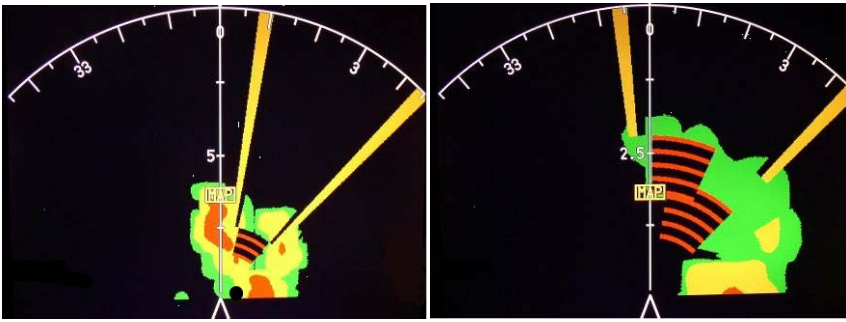
WINDSHEAR TAKE-OFF ALERT REGIONS

WINDSHEAR APPROACH ALERT REGIONS



WINDSHEAR APPROACH ALERT REGIONS

ICON DISPLAY



WINDSHEAR ICONS WITH SEARCH LINES
The windshear icon shown on the display represents the location of the event in both range and azimuth. In the left example, the windshear event begins about 2 nm ahead and 25° to the right of the aircraft. The example on the right shows two icons, indicating two windshear events. The yellow and black search lines help locate the icon in case a long range is selected.

VISUAL PWS ALERT ANNUNCIATIONS

Visual Caution and Warning Alerts are annunciated on the Electronic Displays.

- **Caution Visual Alert:** Amber “W/S AHEAD”
- **Warning Visual Alert:** Red “W/S AHEAD”

AURAL PWS ALERT ANNUNCIATIONS

Caution and Warning Alerts are annunciated by the cockpit audio system.

Caution Aural Alerts may be one of the following (selected at installation):

- Option 1: “Whoop, Whoop”
- Option 2: “Monitor Radar Display”

Warning Aural Alerts are as follows:

- Take-Off: “Windshear Ahead, Windshear Ahead”
- Approach: “Go Around, Windshear Ahead”

PWS SYSTEM FAILURE ANNUNCIATION

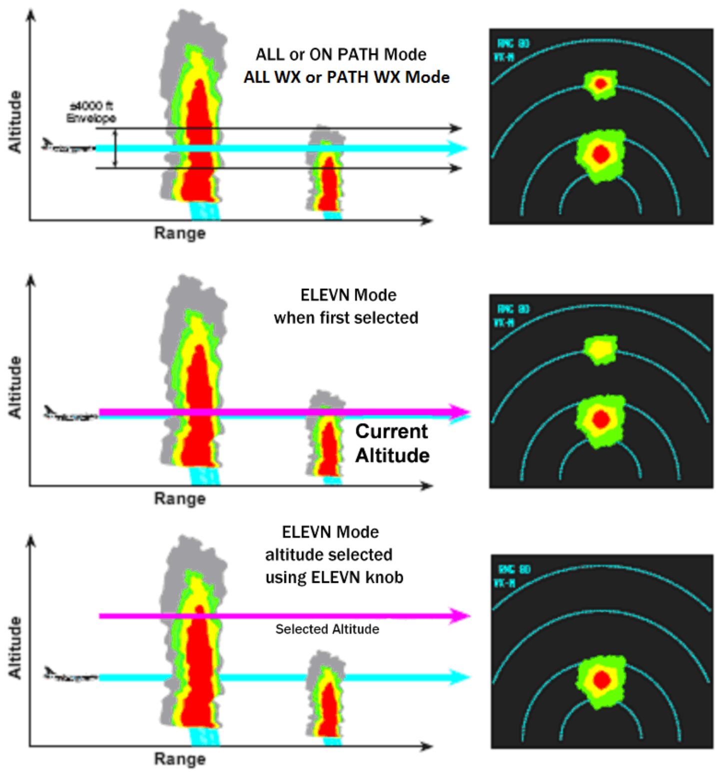
System failures are annunciated on the Electronic Displays. Examples: PRED W/S, PWS INOP, or NO PWS.

WEATHER ANALYSIS

ELEVATION WEATHER MODE

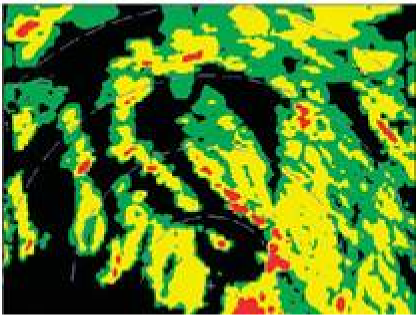
Elevation Weather Mode (ELEVN) provides a means to assess storm cell height and development by providing selectable altitude slices. These slices from the 3D memory are corrected for the curvature of the earth, providing a view at a constant altitude level.

Selecting ELEVN on the mode selection knob enters the Elevation Mode. On initial selection, the altitude slice is set to the current aircraft altitude (nearest 1,000 ft). The Elevation Selection Knob is used to select the desired altitude slice from 0 to 60,000 ft in 1,000-foot intervals. Off path weather information is removed in ELEVN mode to enhance analysis of weather reflectivity. If the Hazard Display features are enabled, turbulence will be shown in ELEVN mode. Otherwise, turbulence is not shown in this mode.



FULL COVERAGE GROUND MAP MODE (MAP)

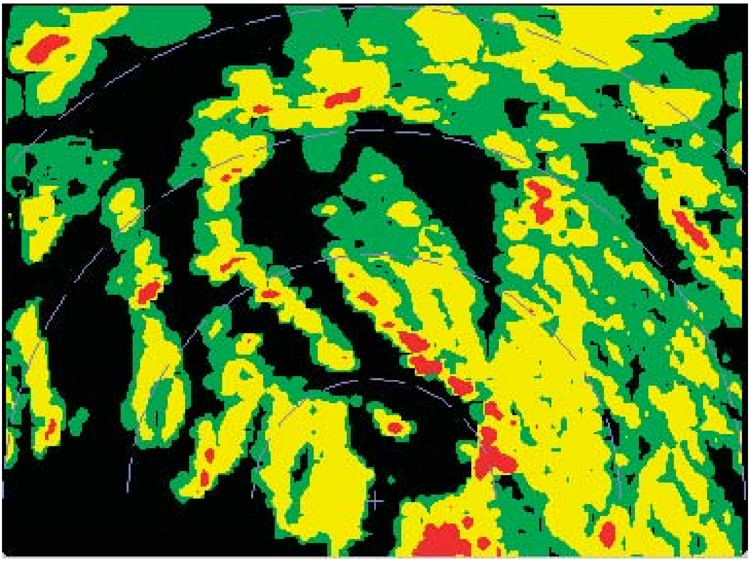
The RDR-4000 Weather Radar System can be used in Ground Map mode to identify terrain features. For ground mapping use the following procedure:



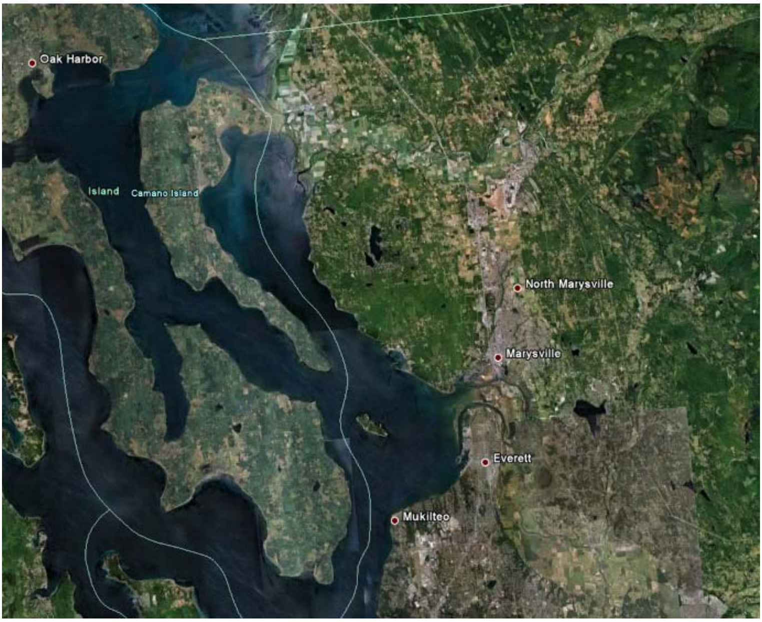
1. System Control: 1 or 2 (dual system) or 1 (single system)
2. Mode: MAP
3. Range: As desired
4. Gain: If necessary, adjust for optimum observation of terrain features.

The purpose of the MAP mode is to aid in identifying prominent terrain features, such as coastlines, lakes, and large built-up urban areas. MAP mode provides an extended ground map picture by piecing together individual scans and combining them in the memory for display. Reflectivity data that is considered ground clutter (and removed from the weather views) is the basis for the Ground Map. Data from the terrain database is not used, providing an independent verification of position. The Ground Map is generated automatically and simultaneously with weather.

See the following pictures for a comparison of a MAP display and a satellite photo of the same area.



RDR-4000 SEATTLE AREA MAP DISPLAY



SEATTLE AREA SATELLITE IMAGE
(Picture from earth.google.com)

GAIN CONTROL (GAIN)

GAIN control is active in all modes. The calibrated (AUTO) position is the only position where the colors represent the FAA defined reflectivity and rainfall rates as shown in the table below. The AUTO gain setting provides a standard reference which all radar manufacturers must follow. Immediately after turning the GAIN control in either direction out of the detent position (AUTO), the “MAN GAIN” annunciation appears on the display indicating that the system is no longer in the calibrated mode. Rotating the GAIN control counterclockwise decreases gain. Rotating the GAIN control clockwise increases gain. The gain setting has no effect on turbulence detection or display. After using gain to assess the weather, the GAIN knob should be returned to the AUTO position.

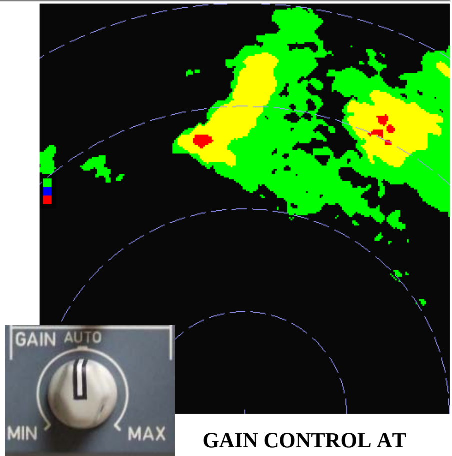
Reflectivity Color Codes (Gain at AUTO)

Color	Returns	Reflectivity	Rainfall Rate
Black	Very light or none	Less than 20 dBZ	Less than 0.7 mm/hr (0.028 in/hr)
Green	Light	20 – 30 dBZ	0.7 – 4 mm/hr (0.028 – 0.16 in/hr)
Yellow	Medium	30 – 40 dBZ	4 – 12 mm/hr (0.16 – 0.47 in/hr)
Red	Strong	40 dBZ or greater	Greater than 12 mm/hr (0.47 in/hr)
Magenta	Turbulence	N/A	N/A

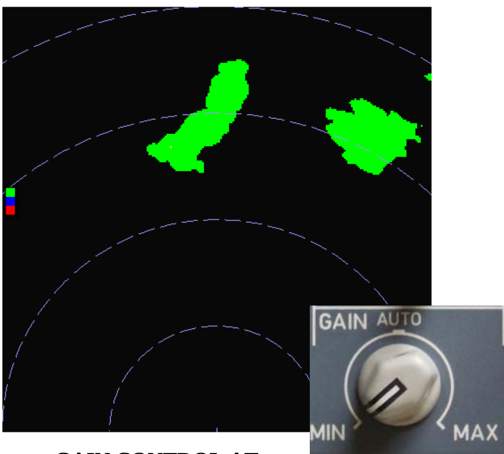
Rotating the GAIN Knob to the minimum (MIN) position reduces gain by approximately 16 dBZ. Rotating the GAIN Knob to the maximum (MAX) position increases gain by approximately 10 dBZ.

Proper use of the gain control can aid in the detection and assessment of storm cells. Gain reduction can be useful in several ways. Reducing the gain to MIN provides a quick assessment of the relative intensity between displayed cells. Since gain does not affect turbulence detection, reducing gain in the AUTO mode to MIN will show turbulence information along with the strongest cells. This is important since the presence of turbulence along with high levels of reflectivity often indicates convective weather. In areas of heavy stratus rain, the display can show large areas of strong returns, but with little associated turbulence.

Reducing the gain can also help identify embedded storm cells within the stratus rain. It can help identify areas of significant attenuation by making radar shadows more prominent. Areas of missing terrain returns in MAP mode that correspond with strong weather echoes may indicate a larger area of precipitation than is apparent on the weather display. (See SHADOWED AREAS on page 44.)



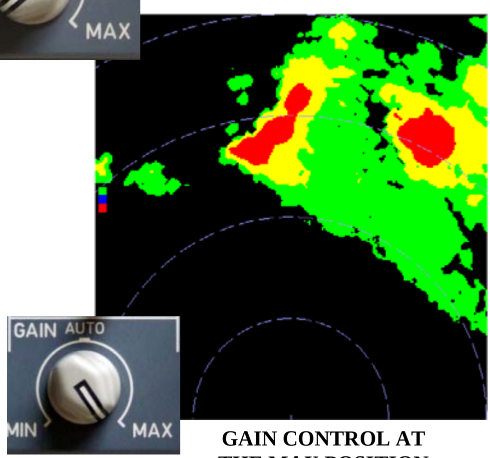
GAIN CONTROL AT THE AUTO POSITION



GAIN CONTROL AT THE MIN POSITION

Use MAX gain only when at cruise altitudes. In ELEVN mode, MAX gain is useful when looking at altitude slices above the freezing level where particles are less reflective. High levels of moisture above the freezing level are key ingredients in hail formation.

Increase the gain briefly at any altitude to discover the relative reflectivity of a weather formation that is visible out the window but does not initially appear on the display. This occurs when the reflectivity of the cloud is below the standard threshold for green weather.



GAIN CONTROL AT THE MAX POSITION

SECTION 4: EQUIPMENT DESCRIPTION

UNIT DESCRIPTIONS

RP-1 RADAR PROCESSOR

The Radar Processor contains the electronics necessary to process the radar data received from the transmitter/receiver, control the modes of the radar and to format the radar data for display. The RP-1 is normally located in the avionics bay.

TR-1 TRANSMITTER/RECEIVER

The Transmitter/Receiver contains the electronics necessary to transmit, receive, and process the radar pulses used to detect turbulence, windshear, weather, and terrain targets. It also contains the system integrity monitoring and self test electronics. The TR-1 is located in the radome in the base of the antenna drive.

DA-1A/B ANTENNA DRIVE WITH FP30-1 ANTENNA

The component parts of the antenna drive are the DA-1A (single) or DA-1B (dual) Antenna Drive and the FP30-1 flat-plate array. The antenna drive, located within the radome, forms the microwave energy into a 3-degree beam. The antenna also receives the return microwave energy, after reflection by weather formations or other objects, and routes these signals to the transmitter/receiver for processing. The antenna drive scans a 160-degree sector in azimuth and ±15 degrees in elevation (tilt).

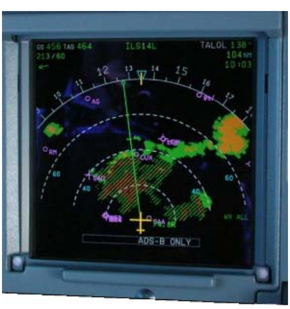
CP-2B CONTROL PANELS

The CP-2B contains all controls for operating the radar system except those located on display units or electronic flight display control panels. The CP-2B is used in both single and dual system configurations.

The RDR-4000 has the ability to show two different radar display views simultaneously. The left side of the control panel controls the left side display (Captain) and the right side of the control panel controls the right side display (First Officer). The flight crew can operate each side independently without impacting radar performance, thus achieving maximum weather information display. The one GAIN control knob affects both displays.

The control panel for installations that include the Hazard Display Features uses pushbuttons for engaging or disengaging the turbulence and hazard display features. These control panels also use different names for some of the mode labels. See *CONFIGURATIONS* on page 5.

ELECTRONIC FLIGHT DISPLAY



The Electronic Flight Display is not part of the RDR-4000 system, but it is where the radar mode or status, weather returns, windshear, turbulence, and ground map data are displayed. This picture is intended as an example only. Your equipment may vary.

OPERATING CONTROLS

While the radar can be turned off completely by setting the System Control Switch to OFF, this is not recommended. The radar operates by continuously scanning the whole sky in front of the aircraft, and saving the results in 3-D memory. On initial activation of the radar, or when switched from one system to the other (**1** or **2**), the radar first looks at the part of the sky that is near the aircraft's altitude. This data is displayed as soon as it is available. As data is gathered from the remainder of the sky in front of the aircraft, the display quickly fills in with any additional information. It takes no more than 30 seconds for the complete picture to become available. Note that when switching from one system to the other, the weather depicted may not exactly match what was previously displayed due to the loss of **historical** data from the other system. Therefore, there is no advantage in switching between systems during flight, except in the case of the failure of one side.

The Display Selection Knob dictates which information is presented to the pilots. For immediate access to the most up-to-date weather display, leave the radar on and turn the Display Selection Knob to OFF if you do not want to see the WXR information on your display.

When it is not safe to transmit, select OFF on both Display Selection Knobs to prevent the radar from transmitting.

SYSTEM CONTROL

To change the System Control Switch to a different position, pull the switch out first, then move it to the desired location.

OFF (center): Turns the RDR-4000 radar and all associated functions off. The radar will not transmit. Predictive windshear detection will not be available.

1 (up): Selects system **1** for normal weather operation.

2 (down): Selects system **2** (if available) for normal weather operation. In single radar installations this position is the same as OFF. To ensure that both systems are used, alternate between systems on successive flights. There is no advantage in switching between systems during flight, except in the case of the failure of one side.

TURB CONTROL

On control panels with a TURB switch, pull the switch out first, then move it to the desired location.

On control panels with a TURB pushbutton, push the button to engage. Push it again to disengage the feature. A light will indicate when the feature is active.

AUTO: Turbulence indications will be overlaid on the weather display in ALL and ON PATH modes.

OFF: Turbulence data will not be shown

ENGAGED: Turbulence indications will be overlaid on the weather display in ALL WX, PATH WX, and ELEVN modes.

HAZARD DISPLAY CONTROL

Push the HZD button to engage. Push it again to disengage the feature. A light will indicate when the feature is active.

ENGAGED: Hail and/or lightning icons will be shown overlaid on the weather display in ALL WX, PATH WX, and ELEVN modes.

OFF: Hazard icons will not be shown.

DISPLAY SELECTION

OFF – When the Display Selection Knob is in the OFF position, no radar display is shown. If a windshear event should occur, the ALL/ALL WX weather mode will be shown, with the windshear icon(s) overlaid. When it is not safe to transmit, select OFF on both Display Selection Knobs to prevent the radar from transmitting.

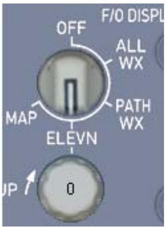
ALL or **ALL WX** – Automatic Weather Mode. Both **On Path** and **Off Path** weather are shown. **Off Path** weather returns are shown with black stripes through them. This mode provides display of windshear out to 5 nm, turbulence out to 40 nm and weather out to 320 nm.

ON PATH or **PATH WX** – Automatic Weather Mode. Only **On Path** weather is shown (**Off Path** weather is suppressed). This mode provides display of windshear out to 5 nm, turbulence out to 40 nm (or 60 nm for PATH WX) and weather out to 320 nm.

ELEVN – Constant Elevation (Weather Analysis Mode). Only weather at the selected elevation is shown. The elevation slice defaults to current altitude upon initial selection. The displayed elevation can be moved up or down in 1,000-foot increments using the Elevation Control Knob. This mode provides display of windshear out to 5 nm and weather out to 320 nm. Turbulence data is not shown in this mode.

MAP – Displays Full Coverage Ground Map. If a windshear event should occur, the **ALL** or **ALL WX** weather mode will be shown, with the windshear icon(s) overlaid.

ELEVATION CONTROL



ELEVN – Controls weather analysis altitude from 0 to 60,000 ft in increments of 1,000 ft. Selected altitude is shown on the Electronic Flight Display. If the pilot’s altitude setting is set to Standard Altitude, the display will indicate the Flight Level (FL) of the depicted weather slice. If the altitude setting is QFE/QNH, the elevation of the weather slice will be given in thousands of ft (KFT).

GAIN CONTROL

AUTO – Rotate to the AUTO position for automatic gain control. The AUTO position results in a calibrated map or weather radar display. Gain control does not affect turbulence or windshear.

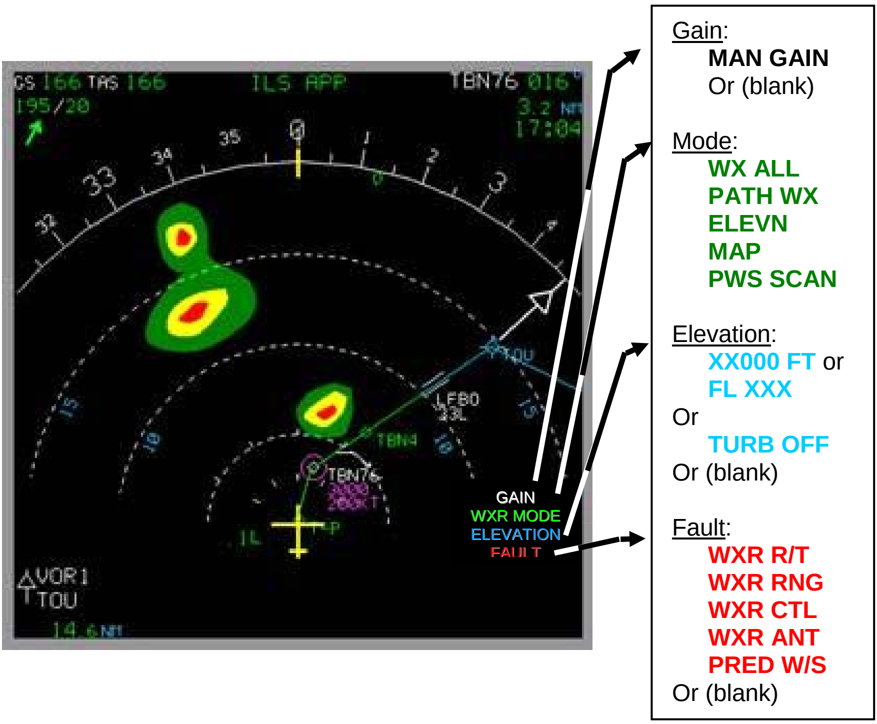
Manual – Rotating the knob out of AUTO varies the gain between MIN and MAX. **MAN GAIN** is shown on the display, indicating that the gain has been changed from the calibrated position.

The **MIN** position reduces the gain by approximately 16 dBZ below the AUTO setting;

The **MAX** position increases the gain by approximately 10 dBZ over the AUTO setting.

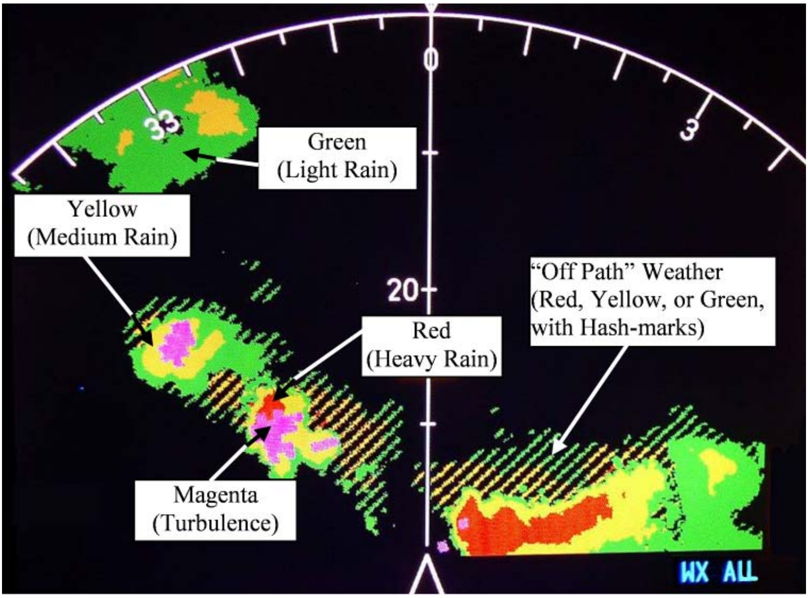
DISPLAY ANNUNCIATIONS

Actual annunciations are display dependent. The following figure is provided as an example only.



WEATHER RADAR DISPLAY ANNUNCIATIONS - EXAMPLE.

DISPLAY COLORS



WEATHER RADAR DISPLAY COLORS

FAULT ANNUNCIATIONS

Fault annunciations alert the pilot that the radar system is not performing to established standards. Built-in test equipment (BITE) automatically and constantly tests the radar system. If a system failure occurs, a generic WXR FAIL message will be annunciated on the display.

Failures will appear as red caution annunciations on the display. Some faults will cause any displayed radar data to disappear entirely.

If the fault does not resolve itself shortly, try cycling power to the system. In a dual installation select the other system. If none of these actions correct the problem, turn off power to the system.

The following table shows some typical fault annunciations. Actual fault annunciations depend on the display in use.

Example of Fault Annunciations

Display Annunciation	Failure
WXR R/T	Radar Processor (RP-1) or Transmitter/Receiver (TR-1) Unit Failure
WXR ANT	Antenna Drive Failure
WXR CTL	Control Panel Fault
WXR RNG	Display Fault
PRED W/S	Predictive Windshear Inop

See the aircraft installation documentation for complete descriptions of the possible failure modes.

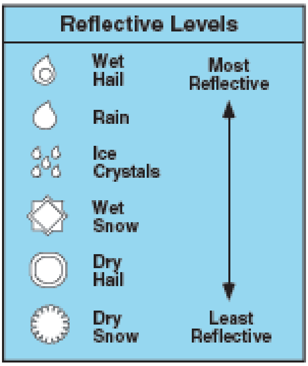
SECTION 5: PRINCIPLES OF WEATHER RADAR USE

WEATHER RADAR PRINCIPLES

Airborne weather avoidance radar, as its name implies, is for avoiding severe weather - not for penetrating it. Whether to fly into an area of radar echoes depends on echo intensity, spacing between the echoes, and the capabilities of both pilot and aircraft. Remember that weather radar detects only precipitation; it does not detect minute cloud droplets. Therefore, the radar display provides no assurance of avoiding inclement weather in clouds and fog. Your display may be clear between intense echoes; this clear area does not necessarily mean you can fly between the storms and maintain visual separation from them.

Weather radar detects droplets of precipitation size. The strength of the radar return (echo) depends on drop size, composition, and amount of water. Water particles return almost five times as much signal as ice particles of the same size. This means that rain is more easily detected than snow, although at times large, wet snowflakes may give a strong return.

Hail usually has a film of water on its surface; consequently, a hailstone is often reflected as a very large water particle. Because of this film and because hailstones usually are larger than raindrops, thunderstorms with large amounts of wet hail return stronger signals than those with rain. Although wet hail is an excellent reflector of radar energy, some hail shafts are extremely small (100 yards or less) and make poor radar targets. If hailstones are cold and dry, they give poor returns and might not appear on the display.



STORM CELL CHARACTERISTICS

Airborne weather radar allows pilots to identify and avoid potential weather hazards. The radar performs signal processing to estimate the radar reflectivity of the weather ahead. Reflectivity correlates to precipitation rate, and is displayed as green (light), yellow (moderate), or red (heavy) precipitation.

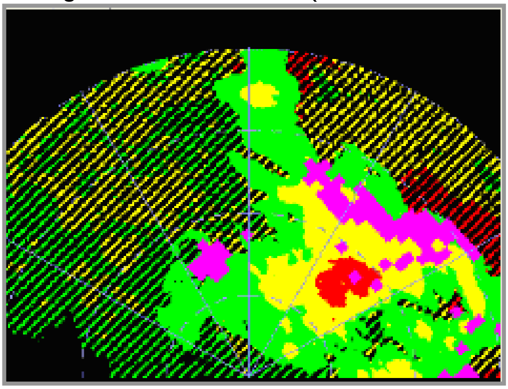
Reflectivity helps to identify the presence of potentially hazardous weather. However, reflectivity alone cannot determine the degree of hazard. It is important that pilots be able to recognize hazards based on the form of the weather (convective versus stratiform), not by observing the reflectivity level alone.

CONVECTIVE WEATHER

Convective weather is associated with hazards due to turbulence, hail, and lightning strike. Recognizing convective weather is instrumental in avoiding these hazards.

Convection results in towering storm structures that can contain high wind gradients that lead to turbulent motion. Very vigorous convection can generate severe turbulence near the high reflectivity core, downwind of the core, and at the top of the storm. The strength of the convection can be judged by the vertical size of the convective cell and the extent of high reflectivity portions of the storm.

The RDR-4000 uses these characteristics to automatically determine the presence of turbulence. At ranges less than 40 nm (or 60 nm if the Hazard Display features are installed) magenta blocks indicate areas of particularly turbulent activity. The radar is capable of measuring turbulent areas of the storm cell at or below the green threshold, thus it is possible to see magenta turbulence indications over green or black reflectivity. Manual mode can be used to reveal the vertical extent of the storm. Note that moisture must be present to detect turbulence. The radar will not detect clear air turbulence (CAT).



If the Hazard Display features are installed, hail or lightning icons will automatically identify areas where those hazards are likely to occur.

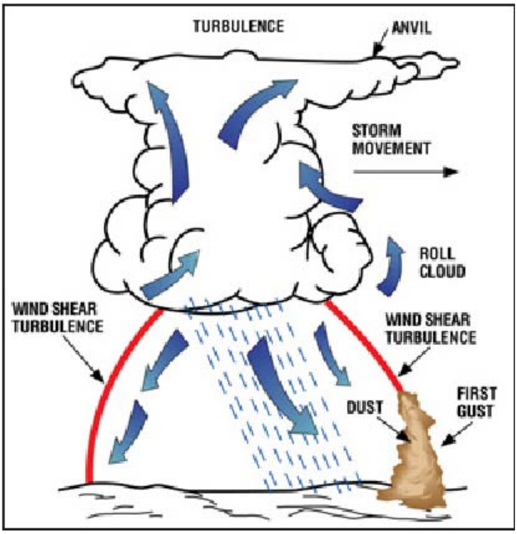
STRATIFORM WEATHER

In addition to reflectivity associated with convective weather, the radar will typically display reflectivity associated with stratus, or stratiform, weather. Whereas convection is characterized by localized towers with updraft and downdraft features, stratiform precipitation results from much more widespread and much less vigorous uplift. As a result, stratus precipitation is more layered in form with much lower gradients in radar reflectivity. However, the reflectivity of stratiform weather can be sufficient to cause yellow and red on the radar display. These high reflectivities result from relatively high rain rates, as well as from enhancement of reflectivity due to melting of snow particles just below the freezing level. High reflectivity of stratus weather does not indicate any significant hazard (with the exception of any potential for icing, or takeoff and landing performance issues associated with high rainfall rates).

ICING

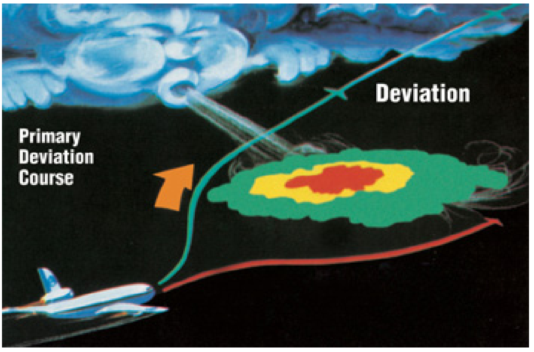
Updrafts in thunderstorms support abundant water; when carried above the freezing level, this water becomes supercooled. As the temperature in the upward current cools to about -15°C, much of the remaining water vapor sublimates as ice crystals. Above this level, the amount of supercooled water decreases.

Supercooled water freezes on impact with an aircraft. Clear icing can occur at any altitude above the freezing level; but at high levels, icing may be rime or mixed rime and clear. The abundance of supercooled water makes clear icing occur very rapidly between 0°C and -15°C, and encounters can be frequent in a cluster of cells.



PLANNING A PATH

Remember to plan a deviation path early. Simply skirting the red or magenta portion of a cell is not enough. Wherever possible, plan an avoidance path for all weather echoes which appear beyond 100 nm since this indicates they are quite dense. If a REACT field is shown, plan to avoid that area since there may be weather there that the radar cannot detect. Refer to the FAA Approved Airplane Flight Manual and to the FAA Advisory Circulars referenced on page 3 for detailed information on flying in the vicinity of and avoiding thunderstorms and turbulence.



PLAN A WEATHER AVOIDANCE PATH IN ADVANCE

The most intense echoes indicate severe thunderstorms. Remember that hail may fall several nm from the cloud, and hazardous turbulence may extend as much as 20 nm from the cloud. You should avoid the most intense echoes by at least 20 nm, if possible. If the Hazard Display features are installed, avoid areas with hail or lightning icons by a similar distance. As echoes diminish in intensity, you can reduce the distance by which you avoid them.

The lightning and hail icons provide additional clues as to whether reflectivity indications are associated with convective developments and provide an indication that the convection may be generating hail and/or lightning. As with any weather radar system, the crew must integrate all possible information including information from sources other than weather radar such as forecast conditions, PIREPs, ground based weather systems and Air Traffic Control when making deviation and penetration decisions.

Also, note that by definition Clear Air Turbulence is always possible in areas of no displayed reflectivity.

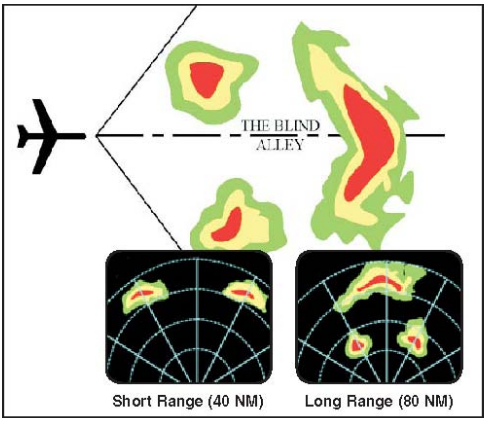
PATH PLANNING CONSIDERATIONS

- Where possible, any indicated reflectivity should be avoided.
- Reflectivity may generally be penetrated if the crew is sure that the reflectivity is associated with stratus (non-convective) rainfall.
    - Stratus rainfall is characterized by widespread, relatively uniform reflectivity, with tops often below 25,000 ft, and with little or no indication of turbulence.
- Weather with tall vertical development (as can be determined using the manual mode), indications of turbulence, lightning, and/or hail should be considered convective and should be avoided.
- Hail and lightning icons identify which cells are likely producers of the associated hazard, but do not explicitly detect the present location of the hail or the lightning. Since lightning and hail can extend a significant distance from the core of the cell, the entire cell should be considered as containing the hazard.
    - Icons are generally placed on the display at or near the center of the area where the hazard-producing convection is located. It is possible that a single icon could indicate the presence of a number of separate hazardous convective cells in order to avoid display clutter. To better resolve the individual convective cells with hazards associated, select a lower display range. It is possible for an icon to appear to have no reflectivity displayed in association with it. However, in this case it should be assumed that the associated convective cell is covered by the icon, and the presence of the hazard in the vicinity of the icon must be assumed.
- Cells with hail icon indications should be assumed to also be producers of lightning.
- Convective cells should be avoided by 20 nm. Characteristics of convective cells include one or more of the following:
    - Cells with large vertical structure (as can be determined using the manual mode)
    - Hail icons
    - Lighting icons
    - Turbulence indications.
- For a build-up of scattered cells where it may not be practical to observe the 20 nm avoidance guideline, plan a path upwind of the cells with the lesser hazard while avoiding other cells by 20 nm. In

areas where the REACT field is shown, expect the possibility of additional weather that may need to be avoided.

- o Generally, consider cells with any magenta turbulence and hail icons as the most hazardous cells, then in order of decreasing severity:
  - Cells with turbulence and lightning indications (no hail indications).
  - Cells with no hazard icon, but with turbulence indicated.
  - Cells with reflectivity only, with maximum reflectivity of red.
  - Cells with reflectivity only, with maximum reflectivity of yellow.
  - Cells with reflectivity only, with maximum reflectivity of green.

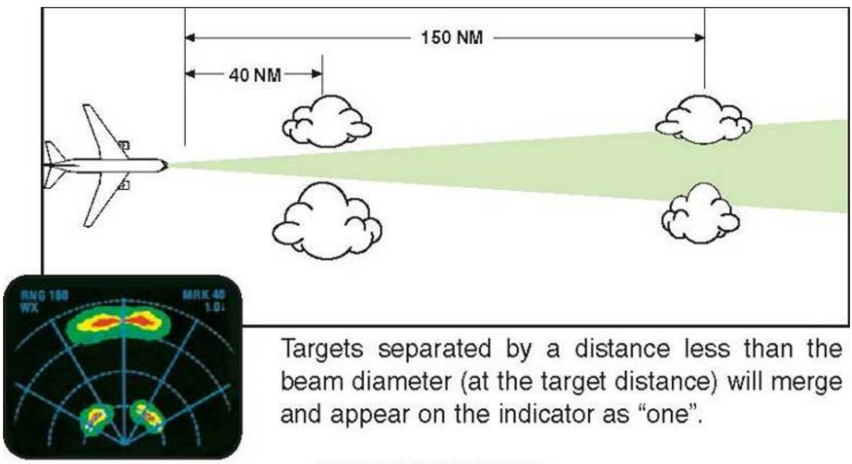
- If a squall line or system of cells must be penetrated, plan a path through the weather in a region of the least indicated hazard with the lowest reflectivity, generally staying upwind of the most severe hazards. In areas where the REACT field is shown, expect the possibility of additional weather that may need to be avoided.
- When REACT fields are shown, the geometry between the aircraft and the attenuating weather may change as the flight progresses. This may allow weather that was in the REACT area to later be outside of the REACT field, and the radar will then more clearly display weather in that area.
- A **Blind Alley** or **Box Canyon** situation can be very dangerous. When viewing the short ranges, periodically switch to longer-range displays to observe distant conditions. In the example shown to the right, the short-range returns show an obvious corridor between two areas of heavy rainfall but the long-range setting shows a larger area of heavy rainfall.



- Thunderstorms build and dissipate rapidly. Therefore, you SHOULD NOT attempt to pre-plan a flight plan course between closely spaced echoes, or under or over convective cells. Avoid individual storms in flight either by visual sighting or by use of airborne radar.

AZIMUTH RESOLUTION

Azimuth resolution is a function of the beam width. When two targets are closely adjacent in azimuth and at the same range, the radar may display them as a single target. However, as the targets are approached they appear to separate. The ability of the radar system to resolve these targets is a function of the antenna's beam width and the range of the target. The limited azimuth resolution also results in storm cells that will tend to appear to be wider in azimuth than the actual width. The increase in apparent azimuth width increases with increasing range.



Targets separated by a distance less than the beam diameter (at the target distance) will merge and appear on the indicator as "one".

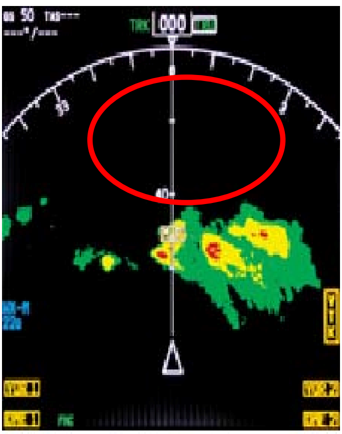
AZIMUTH RESOLUTION

ANGULAR RESOLUTION EFFECT ON VERTICAL RESOLUTION

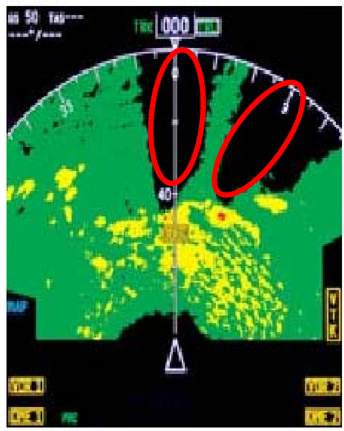
Beam width also has a range-dependent effect on the vertical resolution of weather. The typical effect is to cause the apparent echo tops of the weather to be increasingly higher in altitude than the true echo top as range increases. Although the tops of distant storms may actually be lower than displayed, any decision regarding ability to overfly distant cells should consider the potential for the tops of growing convective cells to be higher than expected when the aircraft reaches the cell location.

SHADOWED AREAS

Extremely heavy rainfall or high terrain can reduce the ability of the radar to penetrate and present a full picture of the weather area. This is called **radar attenuation**. Use MAP mode along with the weather modes to identify areas of shadowing. Observe the ground returns in the area behind the strong weather echo. With very heavy intervening rain, the ground returns behind the echo will not be present but rather will appear as a shadow. This may indicate a larger area of precipitation than appears on the weather display.



Weather display. Note the area of apparent clear weather behind the storm cells. If the MAP display shows a shadow in this area, there may be weather here that the radar cannot see.



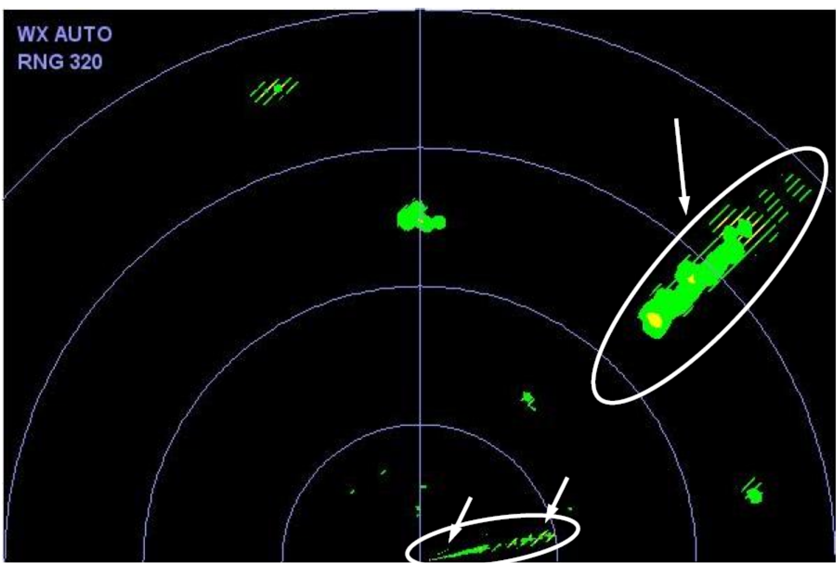
Corresponding MAP display. The lack of radar returns in the circled areas indicates that terrain or very heavy rain in front of those areas prevents the radar signal from penetrating any farther.

EFFECTS OF INTERFERING RF SOURCES

An interfering radio frequency (RF) source operating at a frequency close to the radar's operating frequency can create unusual returns on the display. The interference may appear as occasional isolated dots, or as radial spikes of any color (including magenta) on the display.

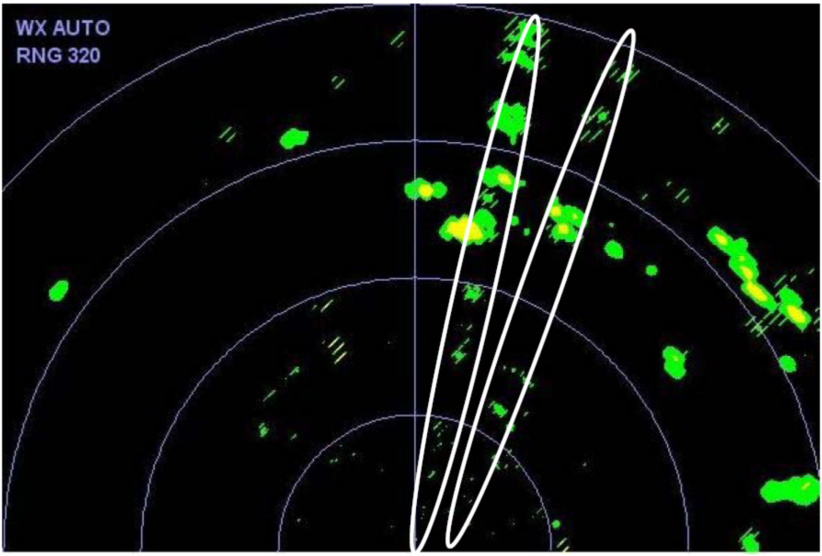
Algorithms in the software suppress most of these returns, but they cannot always be completely suppressed. Once the source of interference is no longer active, the spots will typically be removed after the antenna re-scans the area and updates the memory (approximately thirty seconds).

Adjusting the manual gain may help alleviate the effect of the interfering source but the effect will not completely disappear until the interfering source is no longer in the radar's field of view and that area of the memory has been refreshed.



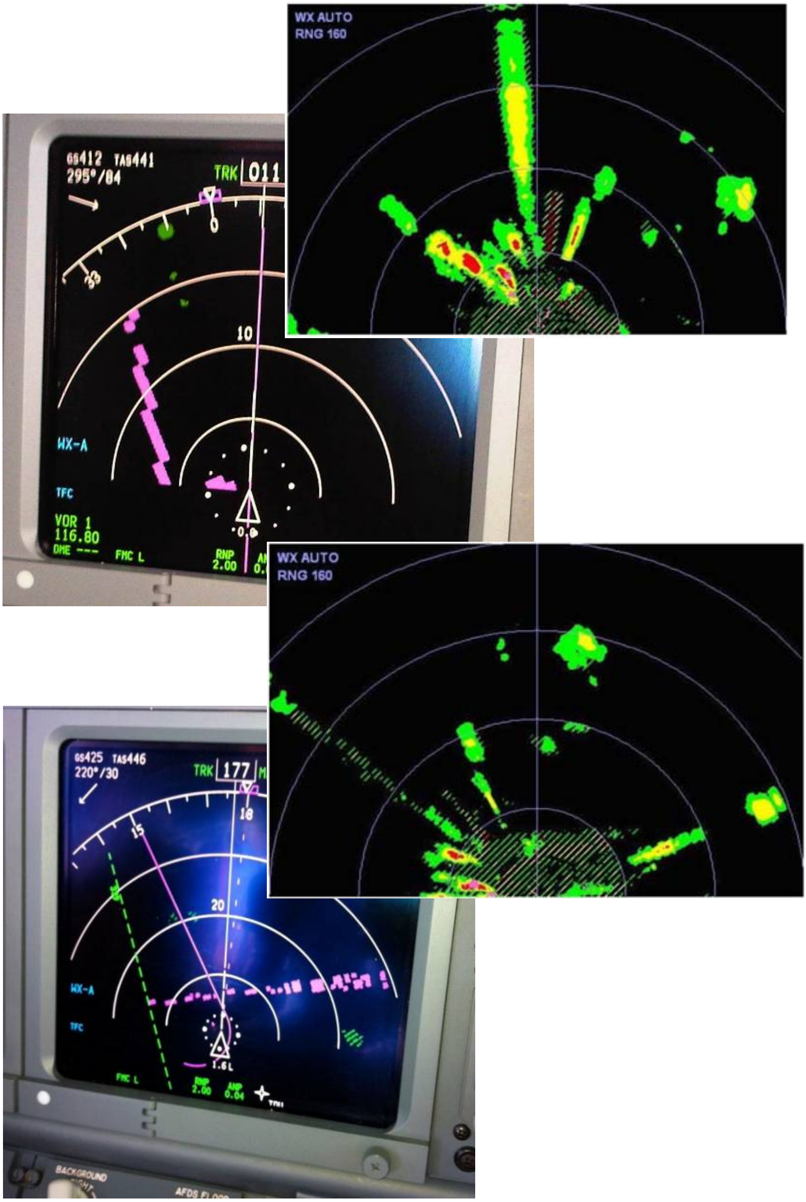
In the above picture, there are at least three sources of interference, at different frequencies.

This figure shows a zoomed-in view of the near-range interference from the previous figure.



In this figure, the interference is a bit more subtle, as it is mixed in with real weather. However, a close look reveals several radial spokes. The two most obvious ones have been circled.

These figures show more examples of RF interference.



RADAR WINDSHEAR DETECTION

During both takeoff and landing, microbursts have been the cause of numerous transport aircraft accidents.

WINDSHEAR/MICROBURST DESCRIPTION

A microburst is a cool shaft of air, like a cylinder, between ½ and 1½ nm across that is moving downward. When it encounters the ground, the air mass mushrooms in a horizontal direction curling inward at its edges. The downward air velocities associated with these narrow air shafts range from 20 to 40 knots.

Two types of microbursts exist; wet and dry. In a wet microburst, rain droplets within the airshaft fall largely intact all the way to the earth's surface. This type of event is typical of humid areas like the southeast United States. A dry microburst may contain virga, or rain that exits from the cloud base, but mostly evaporates before reaching the ground. Virga occurs in high-based rainstorms found in places like the high plains and western United States. Regardless of whether the microburst is wet or dry, the airshaft's wind characteristics are identical.

When the downward moving airflow becomes a horizontal flow at the base of the airshaft, the outflow winds have front-to-back velocities ranging from 20 to 80 knots.

WINDSHEAR/MICROBURST DETECTION PROCESS

When the airshaft of a microburst encounters the ground, it mushrooms outward. By measuring the horizontal velocity of the associated water droplets, the RDR-4000 is able to infer the horizontal and vertical velocity of the winds carrying the raindrops.

The radar processor detects the Doppler frequency shift imparted onto the reflected microwave pulses by a microburst. As the radar scans across the windshear event, it will detect raindrops moving toward it at one range and away from it at a slightly greater range.

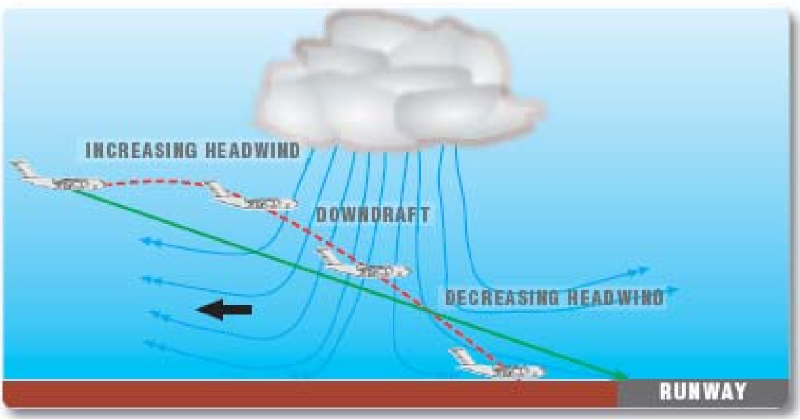
The difference in range between the raindrops moving toward and away is the width of the base of the microburst. After the radar detects this condition, it then assesses the severity of the event by measuring how fast the droplets are moving. If the assessment of the severity of the micro-burst exceeds a preset threshold value, a windshear alert is issued on the radar display and through the flight deck audio system.

The RDR-4000 has the ability to detect the presence of microbursts up to 5 nm ahead of the aircraft when below 1,800 ft AGL.

WINDSHEAR AVOIDANCE FLYING

The air shaft of a microburst creates problems for aircraft for two reasons. The first problem is due to the downward air movement. Since the aircraft is flying within the air mass, as the air mass plummets earthward, so does the aircraft. Second, the lift that is generated by the wing is related to the relative velocity of air traveling over the wing. If the air velocity suddenly changes, so does the lift. When the lift is reduced, the aircraft descends. As an aircraft enters a microburst, depending on the point of entry, it will experience at least one of these conditions and most probably both.

The key to surviving a microburst is to enter it at a high enough aircraft energy state (high altitude and fast airspeed). The RDR-4000 system provides a warning prior to encountering the windshear, significantly improving the chances of surviving the encounter.



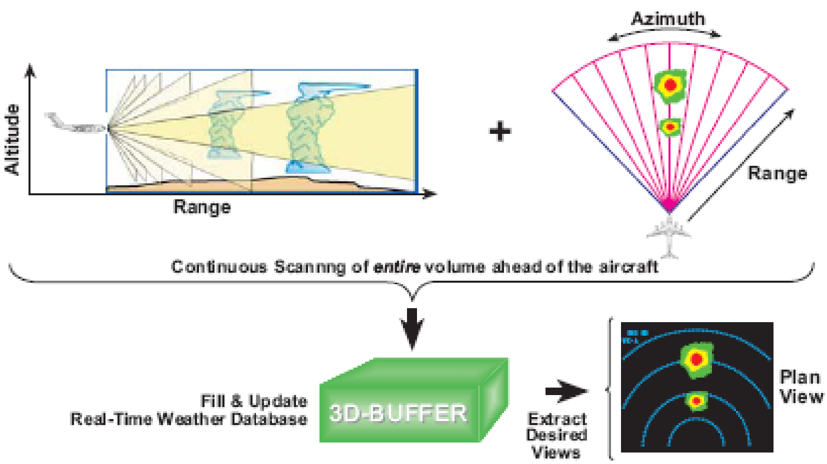
MICROBURST ENCOUNTER EXAMPLE

SECTION 6: RDR-4000 TECHNICAL OPERATION

3D VOLUMETRIC MEMORY SCANNING/PROCESSING

The RDR-4000 collects a complete 3D volumetric scan of all the weather and terrain ahead of the aircraft. The RDR-4000 contains an internal worldwide terrain database, enabling it to extract ground clutter without the significant losses associated with signal-based ground clutter suppression techniques. The data in the memory is continuously updated and compensated for aircraft movement.

In conventional radar systems, there is a one-to-one real-time correspondence between the approximately 4-second side-to-side movements of the antenna, and the radar image update on the displays. In such systems, the display update is synchronized to the antenna tilt angle and sweep. Only the data needed for immediate display is collected and processed. In contrast, the RDR-4000 system has eliminated this limitation. The mechanical scanning pattern of the antenna is de-coupled from the weather images shown on the displays. The radar system continuously scans the entire 3D space in front of the aircraft, and stores all reflectivity data in 3D memory. This memory is continuously updated with reflectivity data from new scans, and the data is compensated for aircraft movement. This reflectivity data is extracted from memory to generate the selected views without having to make (and wait for) view-specific antenna scans.

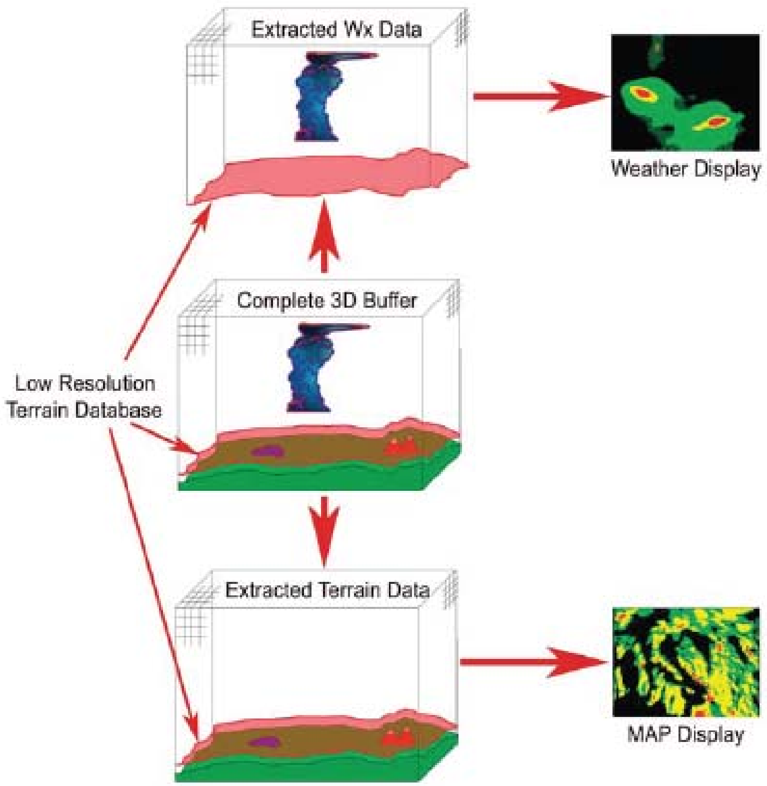


3D SCANNING AND PROCESSING

Views are no longer limited to the single diagonal slice that is inherent to conventional radars. The standard horizontal view of the radar represents a weather envelope based on flight path slope, and corrected for the curvature of the earth. Horizontal views are generated independently for each side of the cockpit.

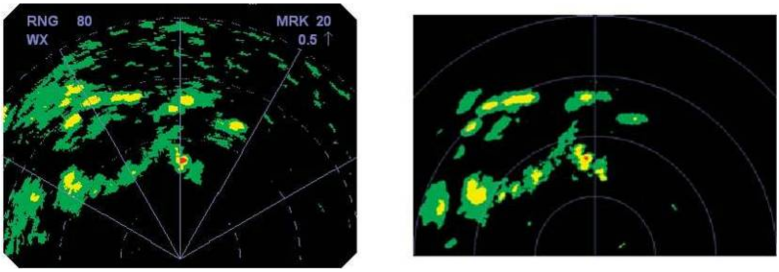
GROUND CLUTTER EXTRACTION

The radar processor contains an internal terrain database with elevation data. The radar compares the collected reflectivity data with the terrain database. Reflectivity data that correlates to terrain data is considered ground-clutter, and is suppressed from the weather images. However, the data that is suppressed from the weather images is retained for display when the radar's MAP Mode is selected.

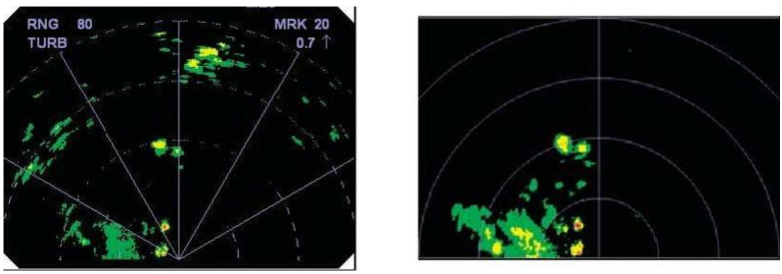


The following pictures demonstrate some of the improved features of the RDR-4000 Weather Radar System.

CONVENTIONAL RADAR RDR-4000



IMPROVED CLUTTER REJECTION / ENHANCED WEATHER PRESENTATION



IMPROVED CLUTTER REJECTION/ENHANCED WEATHER PRESENTATION (ALBUQUERQUE ~70 NM, RIGHT OF TRACK)

ON PATH WEATHER VS. OFF PATH WEATHER

The ALL/ALL WX and ON PATH/ PATH WX modes are used for the strategic detection of weather. This fully automatic weather detection is enabled by the 3D volumetric memory. In these modes, **on path weather**, or weather near the altitude of the intended flight path, is displayed as distinct from **off path weather**, which is further removed in altitude from the flight path. The result is a presentation of weather information that is intuitive, improves awareness of the entire weather situation, and reduces the potential for misinterpretations, thus reducing crew workload.

The separation of **on path** from **off path** weather is based on several parameters:

- Aircraft altitude
- Flight phase (climb, level flight or descent)
- Flight path
- Presence of convective weather.

The separation is done by applying an envelope around the intended flight path: weather within the envelope is considered **on path** weather; weather outside the envelope is **off path** weather. On the display, **off path** weather is distinguished from **on path** weather by black stripes (see illustration on page 34). The flight path angle is computed based on the ratio of calculated vertical speed to ground speed. The expected flight path altitude is extrapolated to 60 nm. Beyond 60 nm, level flight at the calculated altitude is assumed.

ENVELOPE BOUNDARY DEFINITION

The upper and lower boundaries of the separation envelope are based on the parameters listed above. The envelope is not bounded in the horizontal plane. During level flight the envelope extends from 4,000 ft above to 4,000 ft below the aircraft's altitude. At cruise altitudes above 29,000 ft MSL, the lower boundary is extended down to 25,000 ft MSL when necessary to ensure that the most reflective parts of any convective cells are displayed. The upper boundary cannot go lower than 10,000 ft MSL. Additionally, absolute envelope boundaries of 60,000 ft and ground level apply. The resulting rules are shown in the following table.

Envelope boundary limits

Aircraft Altitude (ft MSL)	Lower Envelope Boundary	Upper Envelope Boundary
> 29,000	25,000 ft MSL or Flight Altitude minus 4000 ft	Flight Altitude plus 4,000 ft (max. 60,000)
29,000 to 6,000	Flight Altitude minus 4,000 ft (min. ground elevation)	
< 6,000		10,000 ft MSL

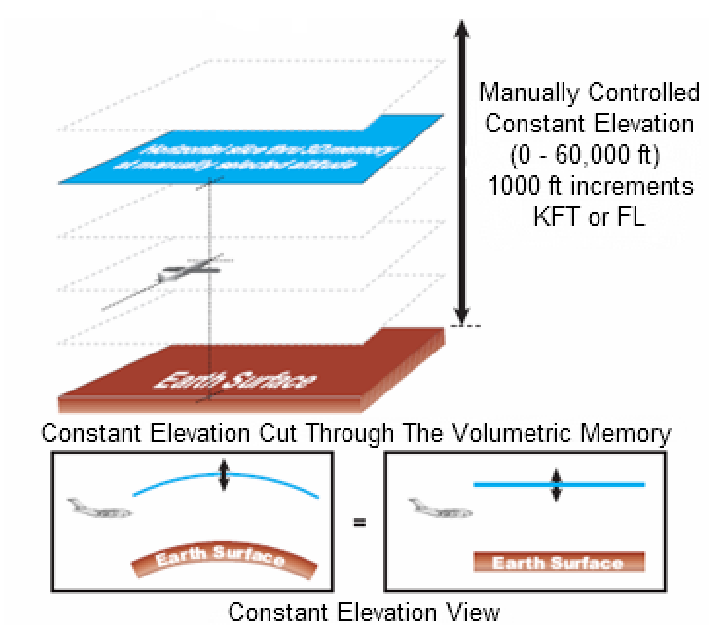
In the ALL/ALL WX and ON PATH/PATH WX modes, the RDR-4000 projects a three-dimensional memory space onto a two-dimensional display. This means the weather displayed for any one memory cell is the color of the strongest return in that column of memory cells. Specifically, if there is any weather data in a given column that is inside the envelope for **on path** weather; the color of the strongest of these returns is displayed. If there is no weather data inside the envelope, then the color of the strongest return from outside the envelope is displayed as **off path** weather if in the ALL/ALL WX mode. In the ON PATH/PATH WX mode, no **off path** weather is displayed.

Stronger returns outside the envelope (**off path** weather) never override the strongest returns displayed as **on path** weather.

WEATHER ANALYSIS MODE: CONSTANT ELEVATION

Constant elevation mode is an analysis mode providing a constant elevation slice throughout the entire 180-degree plan view. It is called constant elevation because the elevation slice extracted from the memory is corrected for the earth’s curvature. With traditional tilt angle settings the earth curves away from the beam far from the aircraft making it difficult to exactly measure the height of a cell. The constant elevation view provides a plan view that represents a thin slice through the volumetric memory of weather reflectivity data. This view is corrected for the curvature of the earth (i.e., it is a view at a constant MSL altitude level or constant Flight Level).

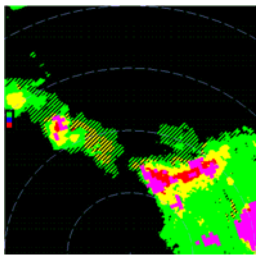
The elevation slice is selected by the ELEVN knob on the control panel. The elevation is selectable between zero and 60,000 ft in 1,000 ft increments. On activation of the ELEVN mode, the slice at the current aircraft altitude (rounded to the nearest 1,000 ft) is chosen. The view



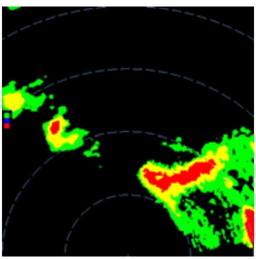
does not move up or down when the aircraft altitude changes. The pilot can quickly measure the tops of cells without any calculations. By varying the selected altitude until a cell just disappears, the cell height can be directly read from the display.

The example below demonstrates the constant elevation mode. In the top center picture the system is in the ALL/ALL WX mode at an aircraft altitude of 20,000 ft MSL. In the second center picture, ELEVN mode has been selected, so this is an elevation slice at the current aircraft altitude (20,000 ft MSL). The remaining pictures show the returns at different elevations. Observe that the cell tops exceed 25,000 ft.

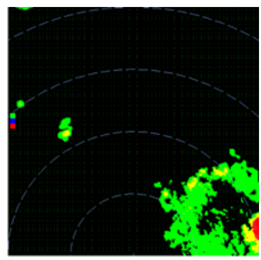
CONSTANT ELEVATION MODE EXAMPLE
USING VARYING ELEVATIONS



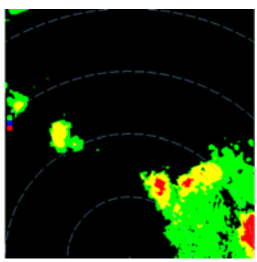
ALL/ALL WX MODE



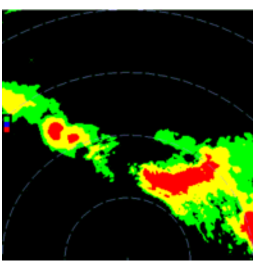
ELEVATION MODE: SLICE AT 15,000 FT



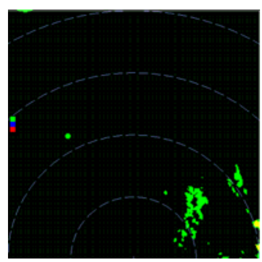
ELEVN MODE: SLICE AT 25,000 FT



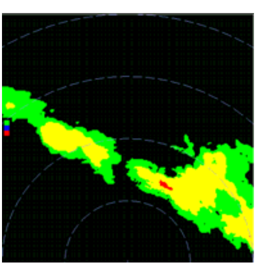
ELEVATION MODE: SLICE AT 20,000FT (e.g. AT A/C ALTITUDE)



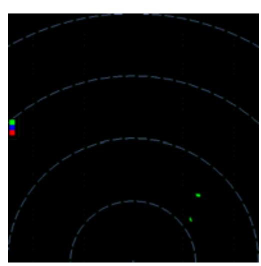
ELEVN MODE: SLICE AT 10,000 FT



ELEVN MODE: SLICE AT 30,000 FT



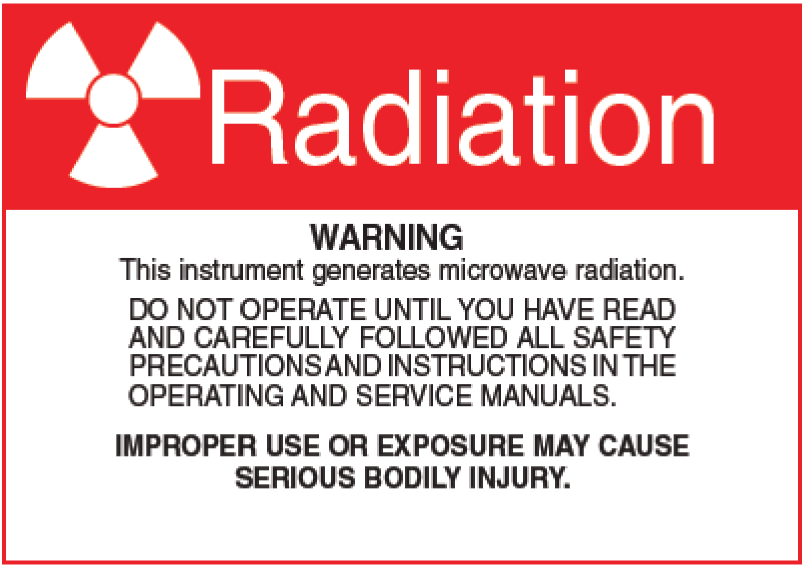
ELEVN MODE: SLICE AT 5,000 FT



ELEVN MODE: SLICE AT 45,000 FT

APPENDIX

SAFETY INFORMATION



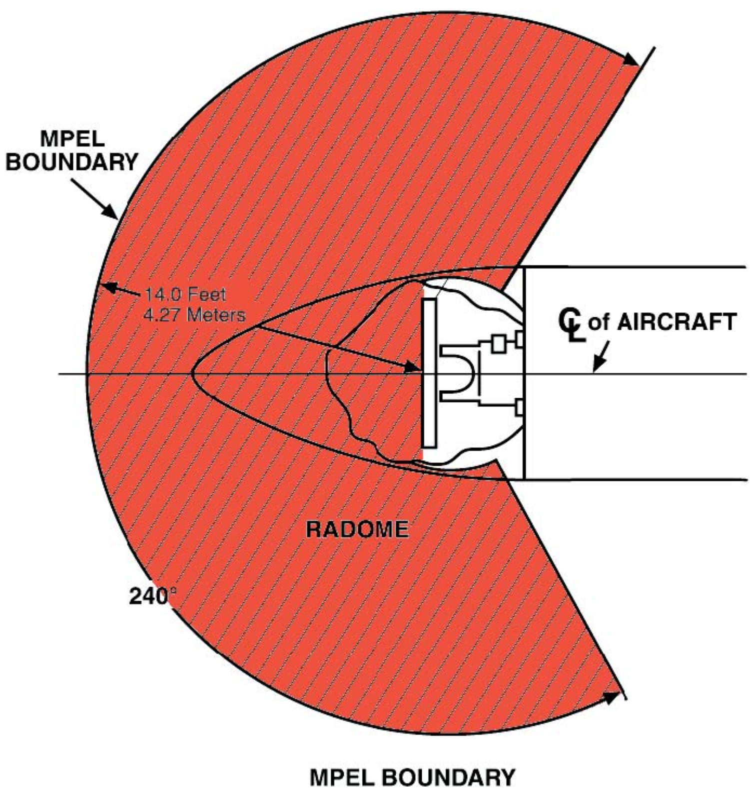
CAUTION

MAINTAIN PRESCRIBED SAFE DISTANCE WHEN STANDING IN FRONT OF A RADIATING ANTENNA.*

*Reference FAA Advisory Circular #20-68B

MAXIMUM PERMISSIBLE EXPOSURE LEVEL (MPEL)

FAA advisory circular AC 20-68B defines the method for determining the MPEL boundary. All personnel should remain beyond the distance indicated in the illustration below. Manufacturers are required to calculate two distances; the MPEL boundary is determined by the greater of these two distances. The first distance is the near field/far field boundary which is the distance from the antenna that it takes for the beam to form. For the RDR-4000 this distance is 14 ft (4.27 meters). The second is the distance where the radiation level exceeds the U.S. Government standard of 10 milliwatts per square centimeter. For the RDR-4000 this distance is 11.8 ft (3.58 meters) from the antenna. In TEST mode the system transmits two 550 microsecond pulses at the beginning of the test sequence and the safe distance is 0.8 inches (2.1 centimeters) from the antenna during this period. The safe fuel distance is 3.5 ft (1.07 meters) from the antenna.



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