



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

April 7, 2020

Attachment 11 – PSA Airlines

Hazardous Weather and Radar Use Training [Excerpts]

OPERATIONAL FACTORS

DCA20CA071

Turbulence

Turbulence is characterized by a large variation in an air current over a short distance. It is mainly caused by

- Jet streams
- Convective currents
- Obstructions to wind flow
- Windshear

Knowledge of the various types of turbulence assists in avoiding it and, therefore, the potential for an airplane upset.

Turbulence

- Turbulence, when extreme, can lead to airplane upsets, and/or structural damage
- These incidents of turbulence can cause large airspeed, altitude, or attitude deviations
- Turbulence encounters may also lead to injury sustained by passengers and flight crew (especially cabin crew)

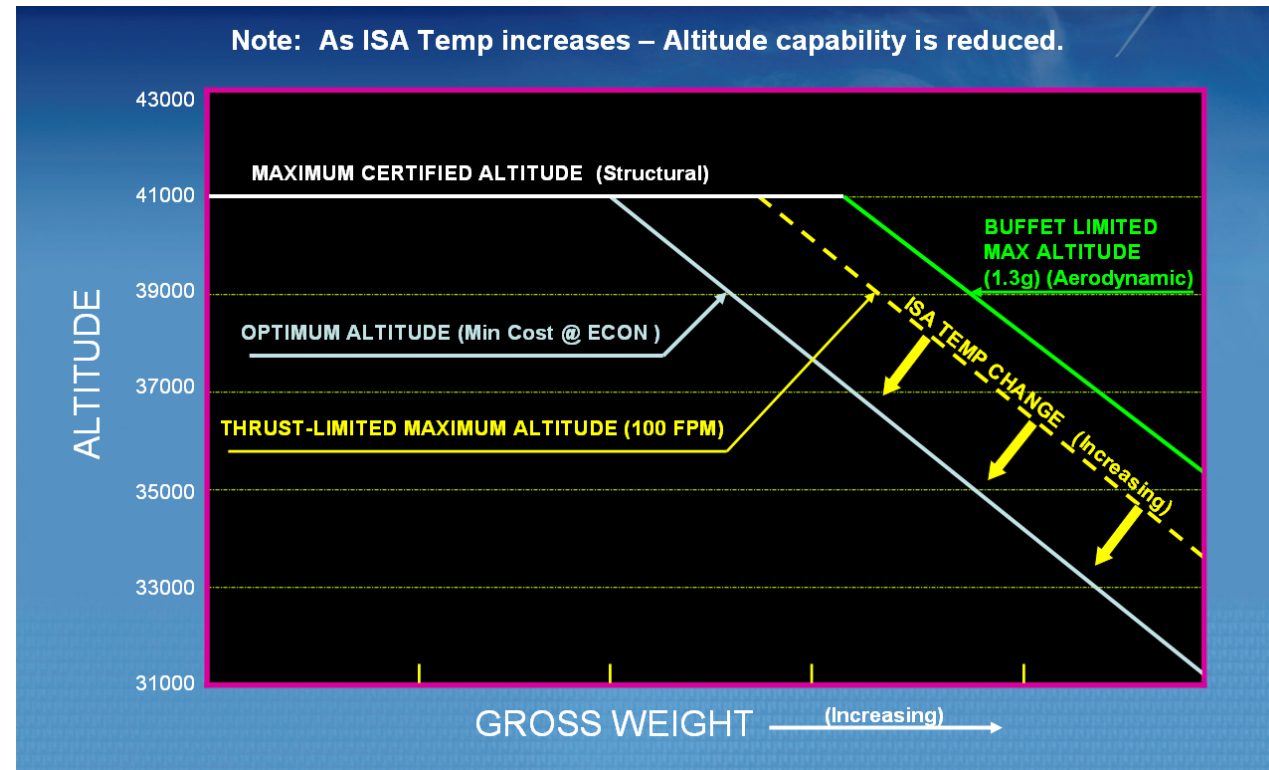
Turbulence

- When flying through turbulence, it may be impossible to maintain altitude while the rapid changes in altitude and attitude may result in over-stressing of the aircraft



Turbulence

- Turbulence can also cause decay of airspeed for Aircraft operating at high altitudes where excess thrust is limited



Clear Air Turbulence (CAT)

Clear air turbulence is defined as:

“High-level turbulence,” as it is normally above 15,000 MSL. It is not associated with cumuliform cloudiness, including thunderstorms. CAT is almost always present near jet streams. Jet streams are dynamic, and turbulence associated with them is difficult to predict. The area of turbulence can be 100 to 300 mi long—50 to 100 mi wide—and 2000 to 5000 ft thick.

Clear Air Turbulence (CAT)

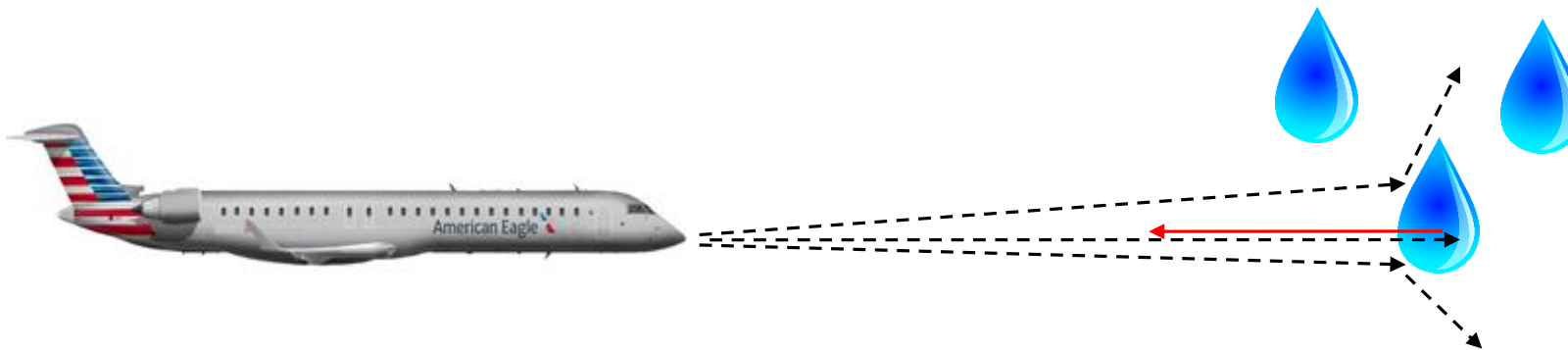
Clear Air Turbulence (CAT) Is Characterized by Marked Changes in:

- Pressure
- Temperature
- Wind direction
- Wind velocity

Weather Radar & Its Use

Radar Basics

- The Collins 840 Radar transmits pulses of radio energy outward from the antenna and then listens for reflective backscatter that is referred to as an echo.
- An echo can be produced by anything with a reflective surface, such as moisture, the earth's surface, or man made objects such as buildings or towers or even cities.
- When using radar to reflect moisture/raindrops, it is the concave side of the raindrop that reflects the most energy back to the antenna.
- The front side of the raindrop (the convex side), reflects radar energy in all directions.
- The larger the raindrop and the more of them that there are, the stronger the radar returns will be.

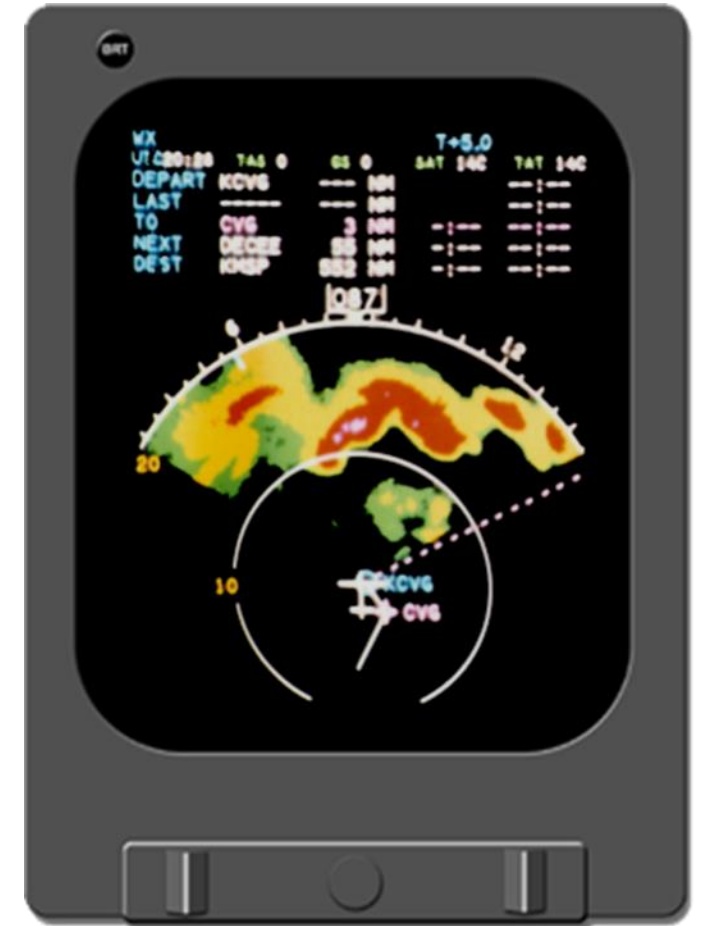


Radar Basics

It is important to understand that radar measures a storm's reflectivity in decibels (DB), which is then displayed on the MFD in a color range.

Most modern radar systems read DB in the following format:

- Level 1 measures up to 30 DB and is green
- Level 2 measures from 30 – 40 DB and is yellow
- Level 3 measures from 40 – 50 DB and is red
- Level 4 measures all reflectivity levels above 50 DB and is magenta



Radar Basics

In addition to DB levels it is important to understand the different levels of reflectivity (from highest to lowest), based on the type of moisture returning an echo back to the antenna.

Reflectivity Levels Highest to Lowest:

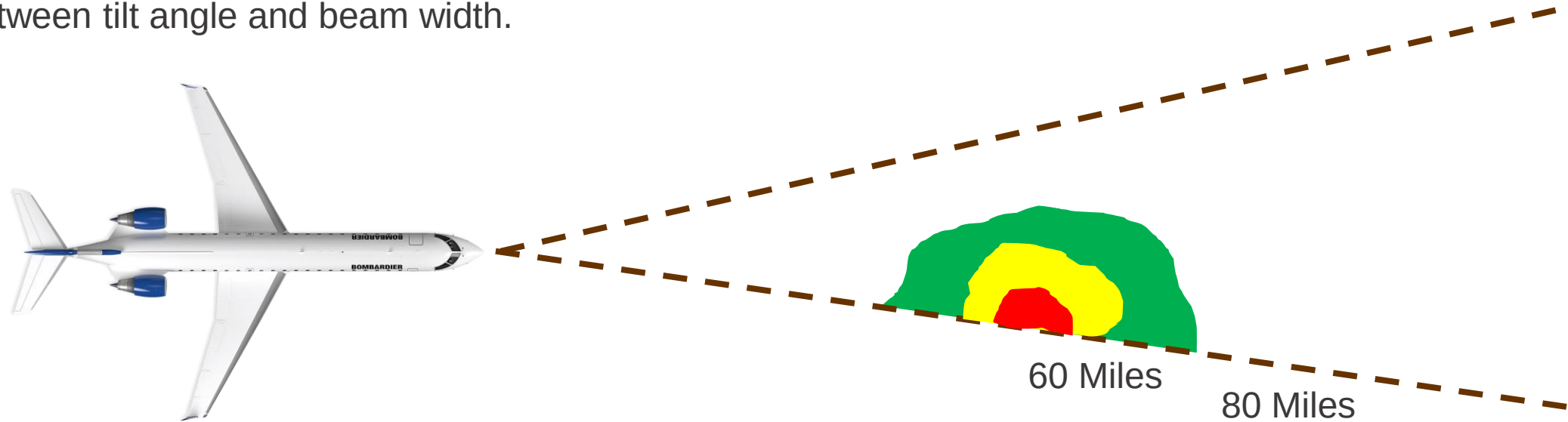
- Wet Hail
- Rain
- Wet Snow
- Dry Hail
- Dry Snow
- Ice Crystals

Radar Basics

The Collins 840 radar works best at a range of 40 to 60 miles and is fairly accurate to a range of 80 miles.

At ranges that start to exceed this the radar begins averaging a larger area and may reduce the severity of a storm's appearance on the radar display.

To better understand this, it will be necessary to discuss the relationship between tilt angle and beam width.



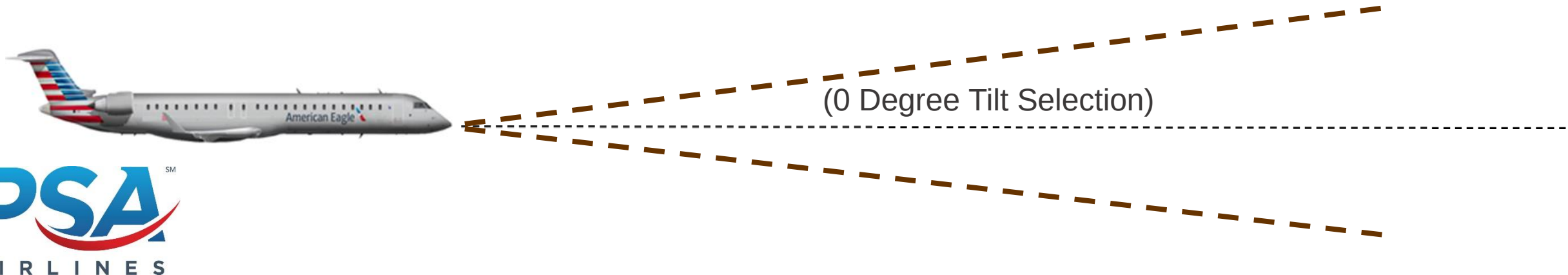
Tilt Angle and Radar Beam

Tilt angle will always (at any distance), be at the center of your radar beam.

As an example at a distance where your beam is 8000 ft. in width, 4000 ft. would be above the tilt angle selected and 4000 ft. would be below the tilt angle selected and at a point where the total beam is 20,000 ft. wide there would be 10,000 ft. each side of tilt angle selection.

At a tilt angle selection of 0 degrees the center of your radar beam, theoretically, would stay level with your aircrafts nose to infinity.

For each 1 degree of tilt above or below 0 degrees, the radar will sweep up or down an area of $1 \text{ NM} = 1 \times 100 = 100 \text{ ft.}$, so at 30 NM with a 6 degree tilt up the beam center would pass through 18,000 ft. ($30 \text{ NM} \times 100 = 3000 \times 6 = 18,000$).



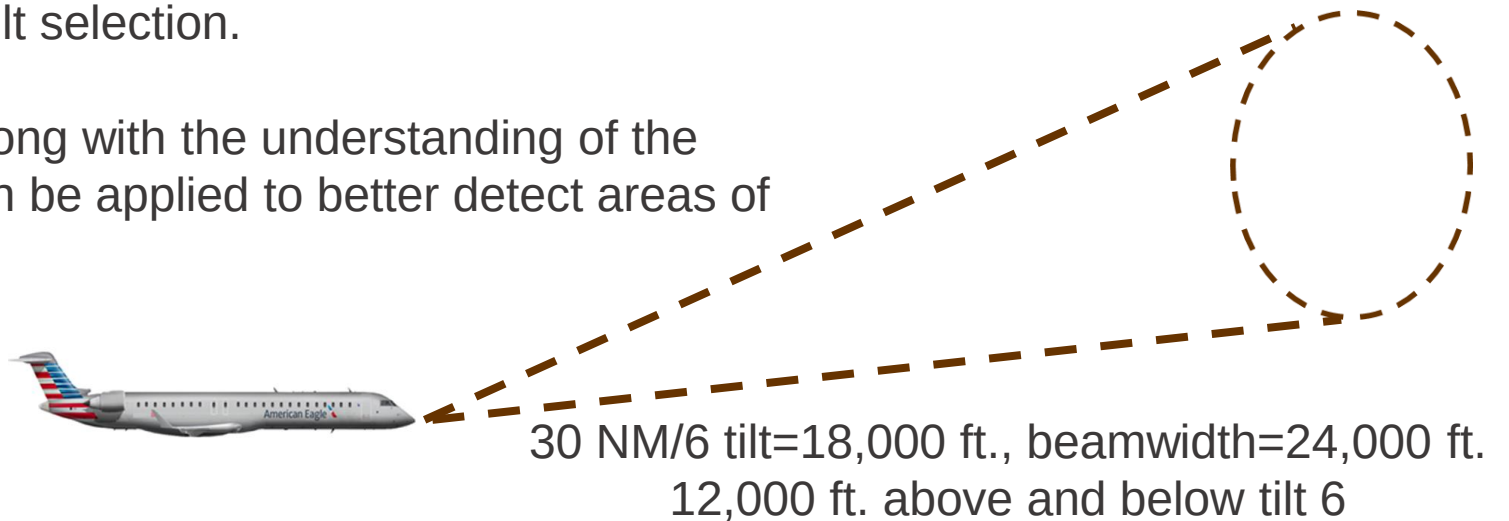
Tilt Angle and Radar Beam

The Collins 840 radar has a 14 inch antenna that yields a beam width of 7.3 degrees (for simple math this can be rounded to 8 degrees).

Total beam width can be calculated by using a similar formula to what we used for tilt angle.
At 1 NM x 8 degrees of width x 100 = total beam width (1 NM x 8 = 80 x 100= 800 ft.).

While using the earlier tilt angle of 6 degrees (which yielded a tilt selection that placed the center of the radar beam at 18,000 ft. at 30 NM) and then applying beam width formula, the total beam width at this range would be 24,000 ft., 12,000 ft. above tilt selection and 12,000 ft. below tilt selection.

The knowledge gained from radar basics along with the understanding of the relationship between tilt and beam width can be applied to better detect areas of precipitation that may contain hazards.

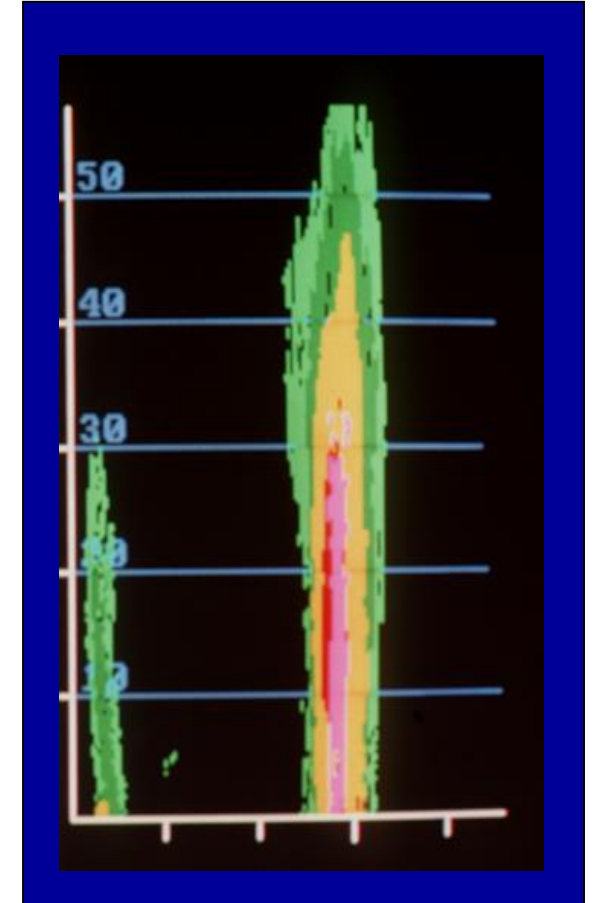


Reading Storms

Most storms that have strong convective force or lifting ability can carry supercooled raindrops and wet hail well above the freezing point.

Wet hail, for example has been found to be lifted as high as 30,000 – 40,000 ft. in some extreme storms. However, the higher the hail or moisture is carried in most storms the more solid or dry it becomes, therefore losing some of its reflective severity (as displayed on the radar) when there is actually an increasing hazard.

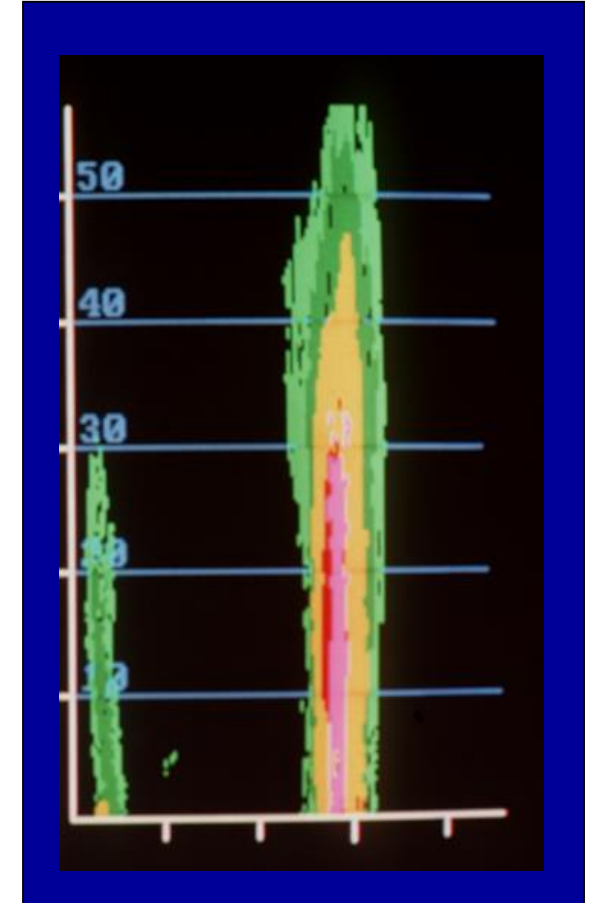
Therefore the best place to take the most accurate reading from a storm is in the mid level range which is roughly 25,000 ft. This is where the most reflective moisture is found (i.e. supercooled droplets and wet hail).



Reading Storms

Always be aware that hail and severe or extreme turbulence can be found in and around any storm, but the likelihood of severe or extreme turbulence and three-quarter inch hail or larger is most likely to occur in storms of 40 DB or greater.

Always be cautious to make sure that before descending, that a storm is not being over-scanned by allowing the radar beam to miss the most hazardous portion of a storm. This may in some cases require placing the radar beam to several degrees of negative tilt angle.

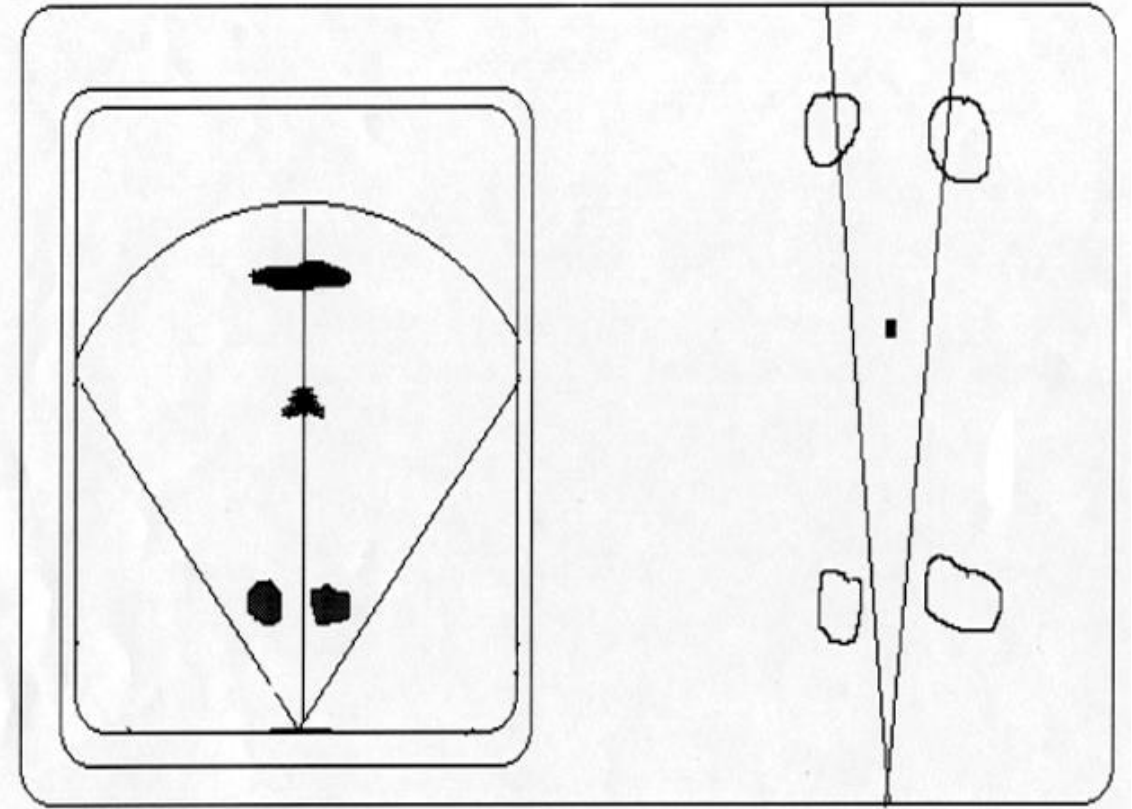


Pitfalls of Radar

Beam Smearing:

Beam smearing potential beyond 40 NM may exist.

This can happen at 40 NM or greater, because the radar may take 2 or more storms that are in close proximity to one another (because of the conical shape of the beam) and average them together showing only 1 storm.



Pitfalls of Radar

Blanked Range:

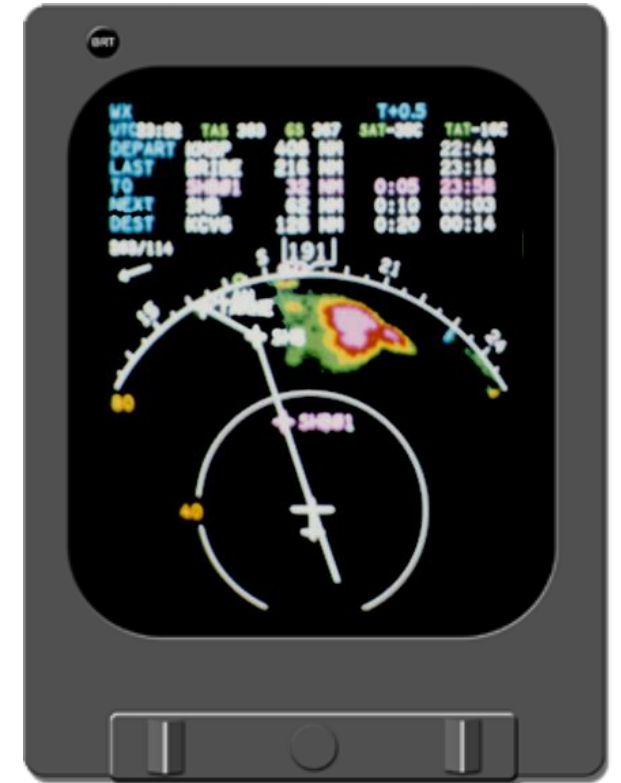
The Collins 840 will always have an 1/8th of the screen (directly in front of the nose) blanked out regardless of the range that has been selected.

As an example, at a range of 160 NM a 20 NM area in front of the nose will be blanked out. At a 40 NM range the blanked area will be 5 NM.

Dry Arid Regions:

Not all storms are equal, as an example a storm in Florida (although still dangerous and should be avoided) is not nearly as dangerous as a storm in drier regions such as southern Utah, but both may appear to be the same on your radar display.

Because of the dry nature of the climate in these dry arid regions/areas, the radar gain should be increased to +1 to have a true picture of its moisture content.



Pitfalls of Radar

Precipitation Attenuation:

Precipitation induced attenuation can happen in two forms.

The first form of attenuation may occur while flying in precipitation. The moisture that is coating the nose cone and the surrounding precipitation can degrade the radars ability to accurately identify weather that is beyond the current position of the aircraft.

This degradation can be as high as 50 %.

To alleviate this the gain selection can be increased to (depending on the severity of the moisture) +1 or +2. This will allow for a more accurate reading of what lies beyond the current moisture the aircraft is in.

Once the aircraft has exited the current area of moisture return the gain back to 0.

Pitfalls of Radar

The second form of attenuation takes place when the leading edge of a storm contains so much moisture that the radar beam is being absorbed and reflected.

This will often produce a shadow. There are times (as in the adjacent example) when the Collins 840 will warn of attenuation by displaying a PAC alert (path attenuation correction) in the area where attenuation may exist.

Don't depend on the PAC alert.

Pilots can check for attenuation by tilting down until you can paint ground returns along the range behind and to the side of the area in question. If a shadow still exist **DON'T FLY THROUGH THIS AREA IT'S ATTENUATING.**

NEVER FLY THROUGH OR NEAR A RADAR SHADOW



Radar Control Panel

Gain Knob:

- Each digit will select an increase or decrease in gain by 6 DB or 1 color intensity.
- In dry arid regions we can increase gain by 1 level to more accurately identify a storm's reflectivity. We can also choose a negative gain of -1 to clear returns from the radar that are adding clutter to the overall picture while on approach to land. This will allow level 3 and 4 storms to be more easily identified and circumnavigated if needed.
- Pushing the center of the gain selection knob will enable ground clutter suppression for up to 12 seconds.



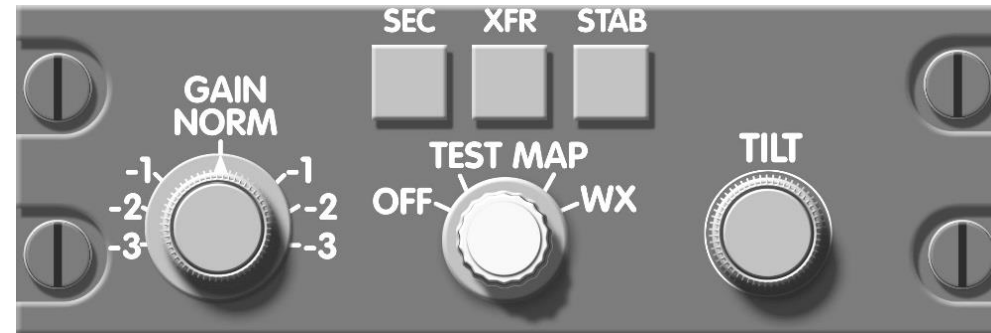
Radar Control Panel

Mode Select Switch:

- When radar is not powered, RDR OFF is displayed on the MFD.
- By placing the switch in TEST and the GAIN set at 0, all four color ranges will be displayed on the MFD, as well as a thin PAC alert band should appear on the outer most range band selected.
- MAP: ground mapping targets are displayed from least to most reflective.
- WX: reflective precipitation is displayed in green, yellow, red, or magenta.

Sector Scan Switch:

- The normal sector scan for the Collins 840 is 120 degrees (60 either side of center).
- Pressing the sector scan switch will change the sector scan to 60 degrees (30 either side of center). This will update the radar at twice the speed and is very useful on an approach in the terminal area where a quicker update may be necessary.



Radar Control Panel

Transfer Switch:

- PSA aircraft have dual weather radar control panels. Although there is only one radar antenna installed, both pilots may select different range, tilt and gain settings. While the radar sweeps from left to right the Captain's display is updated based on the selections made from the Captain's control panel. When the antenna sweeps from right to left the First Officers display will be updated based on the selections on the First Officer's control panel.
- When both weather control panels are in operation, selecting the XFR button transfers control to the cross side control panel. When selected, both display control panel range and tilt settings synchronize to the controlling side. When transfer is selected the radar presentation is updated twice as fast as in the normal position (both radar displays are updated on each sweep of the antenna). Pressing the switch again will change the system back to independent.



Radar Control Panel

Stab Switch:

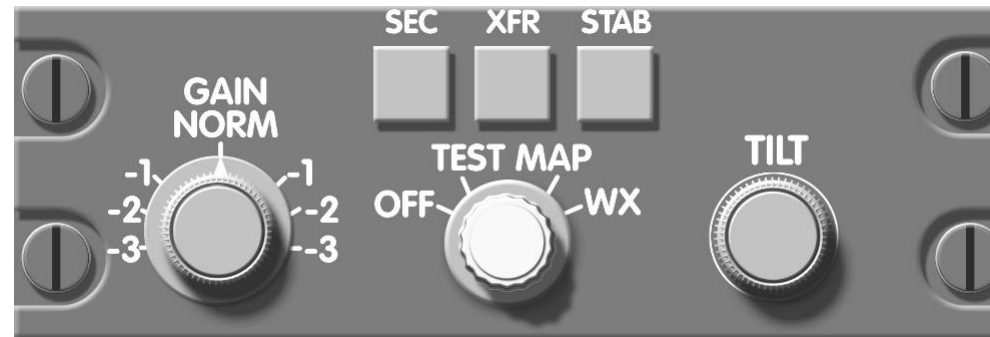
- *Push in:* the antenna is stabilized by your attitude heading reference system and will maintain a level sweep of the beam regardless of pitch or roll attitude.
- *Select out:* the antenna will no longer display a level sweep when pitch or roll are changed and will display USTB in the upper right corner of the MFD data lines. **THIS IS NOT THE DESIRED POSITION.**



Radar Control Panel

Tilt Knob:

- Rotating this knob will change your tilt angle as much as +/- 15 degrees. To understand tilt and radar beam please revisit earlier discussion.
- *Push in:* Selects or deselects antenna auto tilt (an A will appear on the MFD data line behind the tilt angle section when in auto tilt).



Display Control Panel:

- *Radar Terrain Switch:* press to select radar or terrain on the MFD



Tips and Techniques

Prior to Taxi:

- Prior to taxi the crew should be using weather reports and forecast to determine what might be encountered on the flight. Also with the use of the WSI RADAR app a crew can start to develop a plan of attack for deviating around weather and also for determining how severe the weather is along their route of flight and at what point they might be the most likely to encounter weather. This might also help determine the need for more fuel.
- Don't forget the dispatcher, because they have access to weather radar and can give updates on weather both on the ground and via ACARS in the air. Your dispatcher may also have information from other flights that have travelled through the same area.
- Don't be afraid to query ATC for a more accurate picture. Remember most terminal and enroute facilities have a much larger view of the weather a crew may be encountering. The crew only has a small sampling of their surroundings in relation to their direction of travel.

Tips and Techniques

Taxi and Take Off:

- After the crew has pushed off the gate and the ground crew are clear of the two foot radar hazard area, TURN IT ON, IT'S FREE.
- When the crew suspects weather in the local area, turn the radar on and start to use it on the taxi out. This can help the crew to plan for any weather that may exist in the departure area. Remember that during the taxi the nose generally will change directions allowing the crew to start sampling different departure sectors. If a crew feels they need more time to scan weather in the area, coordinate with ATC and pull over in a ramp area that is not congested and point your nose in the direction in question and do a quick scan with the radar.
- What tilt angle and range should the crew use in this phase ? Usually a tilt selection of +5 to +6.5 degrees of tilt up and a range selection of 40 NM. By selecting this tilt and range the crew can eliminate a majority of ground clutter from the radar presentation, therefore allowing the crew to identify radar returns from moisture more clearly. Maintain this for the initial take-off roll and climb in the terminal area.

Tips and Techniques

Climb:

- As altitude increases during climb, it will become necessary to start adjusting the tilt angle down. As a general rule of thumb you should lower your tilt by 1 degree per 5,000 ft. of climb. At about 15,000 ft. the tilt should roughly be about +2 degrees. Also the crew should keep in mind that when passing through 5,000 or 6,000 AGL, longer range settings may be selected.

Tips and Techniques

Cruise:

- Upon reaching cruise altitude, select the range desired and adjust the tilt angle until ground clutter appears at and along the width of the top of the radar display. Depending on your altitude, this may be a negative tilt angle. This tilt method will enable the crew to view weather above and below the current position and should allow your beam to scan the 25,000 ft. range of a storm which is the most reflective. Some other tips for a momentary change of tilt for reading weather at the current altitude and above, is to take half of your beam width (which is 4 degrees), and raise your tilt by that much above 0 and this should place the bottom of the radar beam level with your current altitude out to a range of 40-60 NM. By doing this a crew can have a rough idea of weather that is extending into their flight path at the current altitude. Once you have checked this area be sure to return the tilt back to the previous position.
- Do not attempt to overfly or under fly or penetrate any storm cells or squall lines. Radar is an avoidance tool. Crews should always be vigilant to make sure that the tilt is being strategically used to scan the area well below the current altitude prior to any descent to make sure that an over scanning of weather will not occur.

Tips and Techniques

Descent:

- Antenna tilt should be raised approximately 1 degree per 10,000 ft. of descent down to 15,000 ft., then 1 degree per 5,000 ft. below 15,000.
- Range should be adjusted as necessary to scan the arrival route adequately.
- In heavy weather, the longest appropriate range should be used to plan a safe avoidance route.
- Remember that more tilt adjustment will be needed each time the range is changed.

Tips and Techniques

Terminal Area and Landing:

- Upon reaching the terminal area the tilt should be adjusted to +4 or +5 degrees and the range should be down to a selection of 40 NM. This will keep ground clutter to a minimum and will better help to more accurately identify weather threats.



- As the aircraft begins to approach a distance of approximately 7 miles from the threshold and there is potential for weather close to the field the SEC switch can be selected, so the radar will update the crew twice as fast as to the movement of close in storms in relation to the field. Crews at this point can also run the range scale down to 10 NM and raise the tilt angle to +10 or +15 degrees (which will eliminate most confusing ground clutter) and decrease gain to -1, this will allow for any storms that are still showing as magenta to be identified because they can contain severe wind shear and micro burst potential.

Weather Tips

- Most weather that affects a crew will have tops at 15,000 ft. or above (exceptions would be for bands from a hurricane) and weather that starts to extend into the altitudes above this should be circumnavigated by a wide margin when able. Any storm that grows into regions that exceed this can have the potential hazards of hail and severe turbulence that can be experienced well outside of the radar return.
- Super cells should always be circumnavigated on the upwind side when possible and crews should also note the wind vector on the MFD so that a prediction can be made about where hail may be encountered near the storm.
- Never fly into the red.
- Never fly into or near a radar shadow.
- Never fly into a yellow area where the yellow is part of a steep gradient that is touching a red return.
- When you are in visual conditions and the crew can see an anvil or an overhang avoid flying under this area due to its potential for severe turbulence, hail and lightning.

Weather Tips

Airmass Thunderstorms:

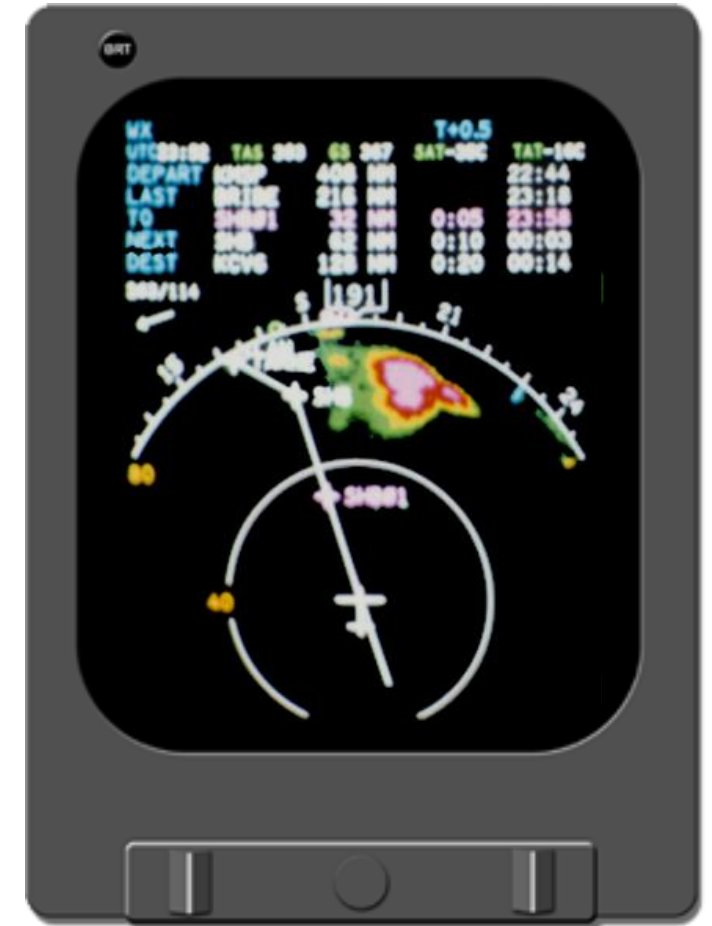
- Develop individually or in clusters
- Short lived
- Easily avoided
- Can produce microbursts



Tips and Techniques

Super Cells:

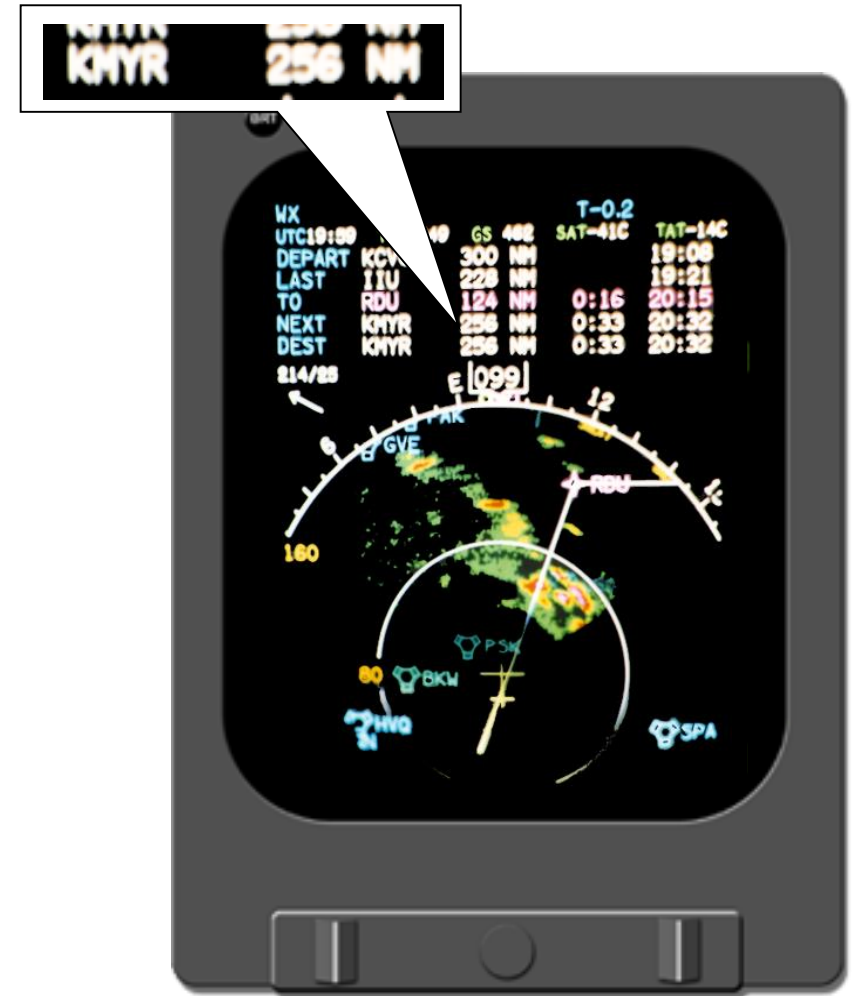
- Intense reflectivity
- Asymmetrical color gradient
- Less reflectivity on the down wind side (indicates shearing)
- Often associated with squall lines/fronts
- Can last for hours
- Can develop alone
- Always circumnavigate on the upwind side and expect rapid changes



Tips and Techniques

Squall Lines:

- Can precede a cold front by several miles and appear as a bow shaped echo.
- Fast moving
- Rapid changes
- Extended areas
- Often violent storms



Tips and Techniques

Convective Rain:

- Localized echo
- Greater reflectivity
- Steep well defined gradient
- Considerable vertical development

