Airborne-Weather-Radar Interpretation
Ian Gilbert

This familiarisation is targeted for aircraft equipped with Honeywell weather radar. The fundamental principles are, however, applicable to all weather radars in all aircraft.

Weather-Radar Operating Principles and Interpretation.

Presented by
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1st November 2005

Radar Principles and Operation

Goals of the Radar:

(1) Find the distance to an object (often called a radar target).

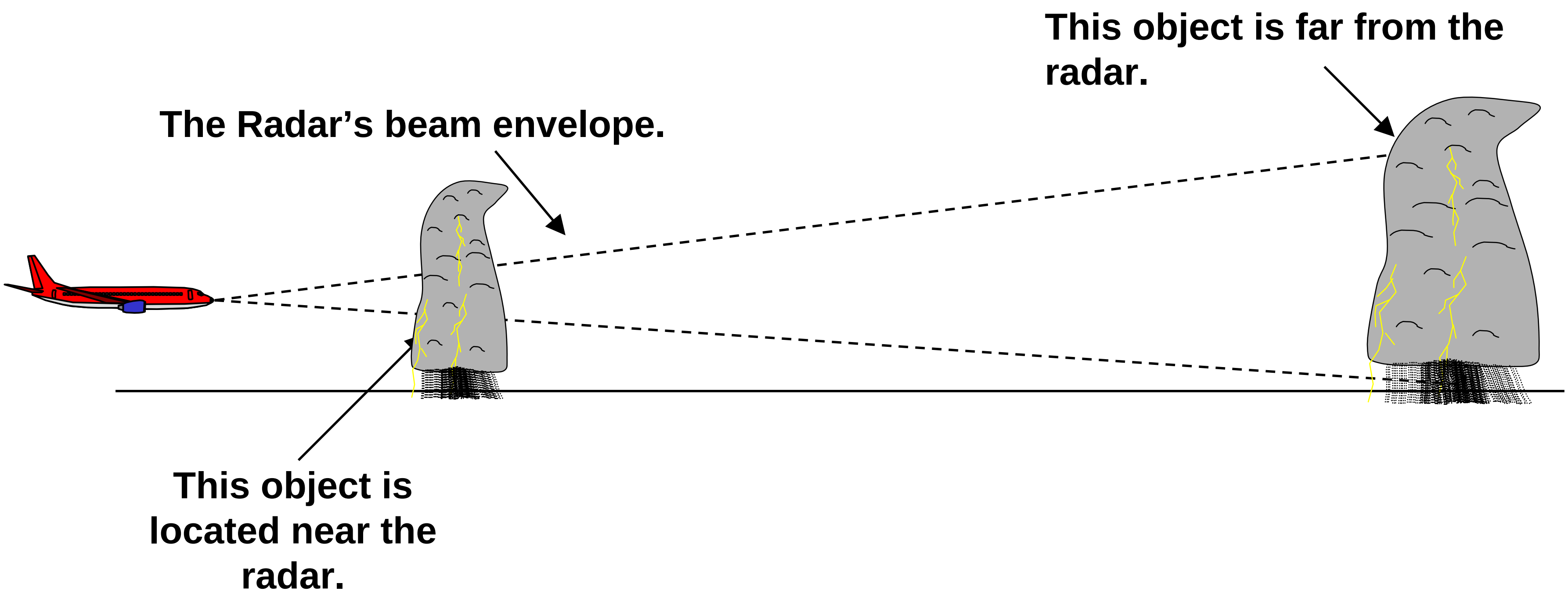
(2) To find the direction to the target.

(3) To determine the target's reflection characteristics.

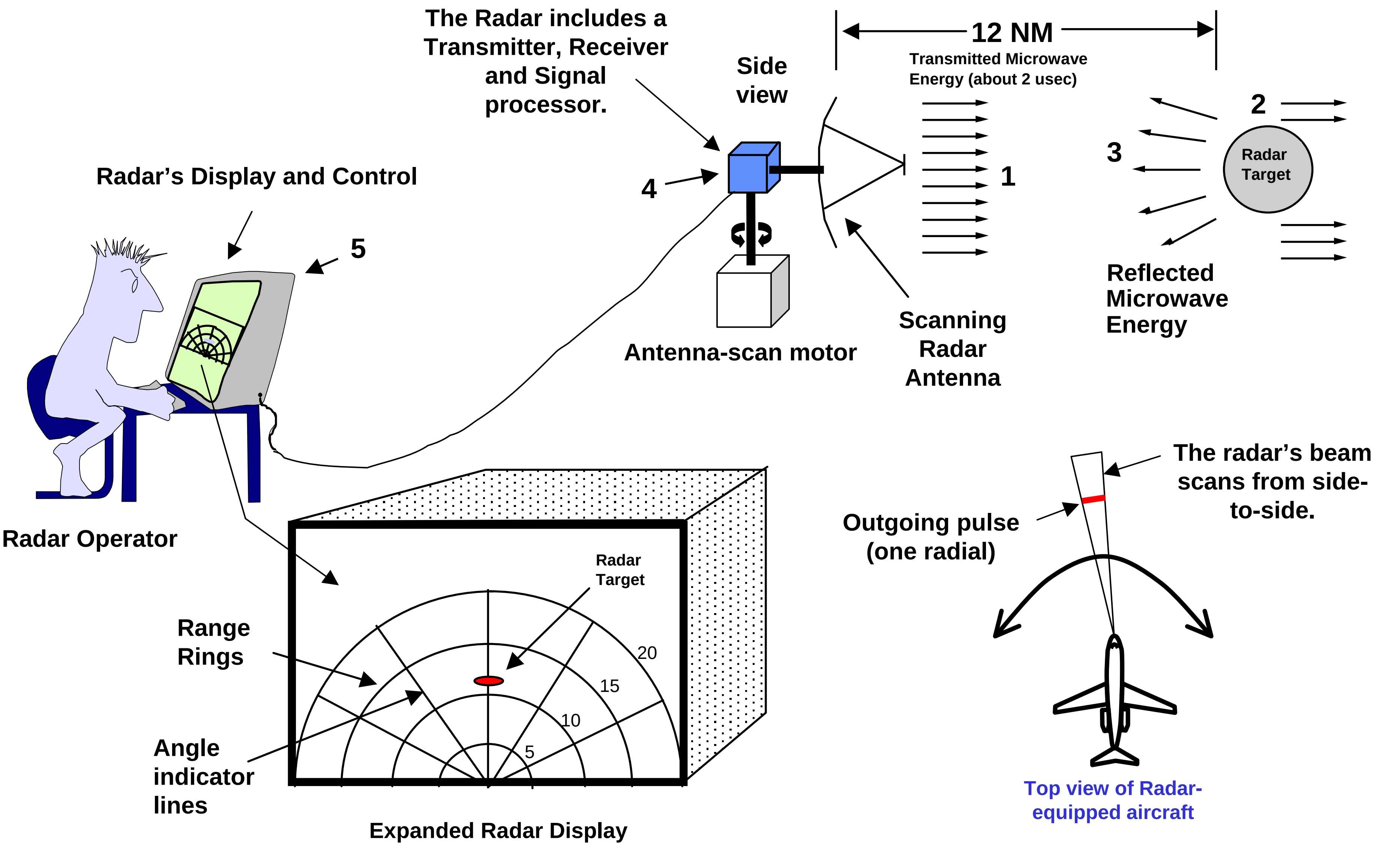
Here is how it works:

Radar Principles and Operation

The name RADAR is a contraction of the words RAdio Detection And Ranging.



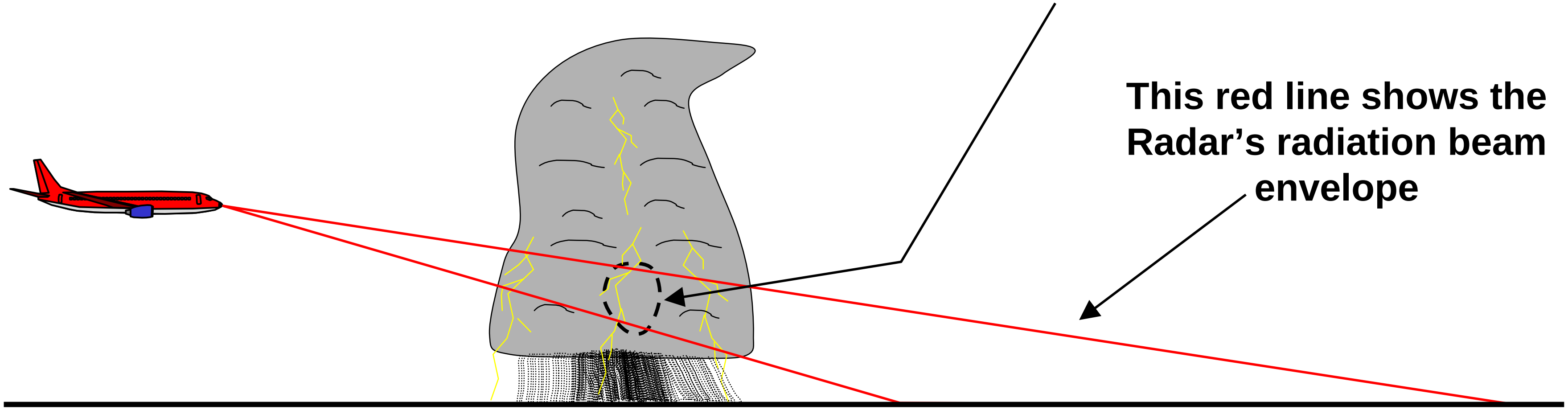
Radar Principles and Operation



Here is the most important single point to note:

The dashed line shows where the most reflective part a thunderstorm is located.

This red line shows the Radar's radiation beam envelope



That procedure produces a calibrated-weather presentation.

Once you learn the correct technique, operating a weather radar is relatively straight forward.

(1) Finding the Target's Distance

Radar-signal-travel time = 12.34 micro seconds per nautical mile.

When the radar transmits, it starts keeping track of the travel time.

When the signal returns, the round-trip travel time is recorded.

A target at 100 NM range = 1,234 micro seconds travel time.

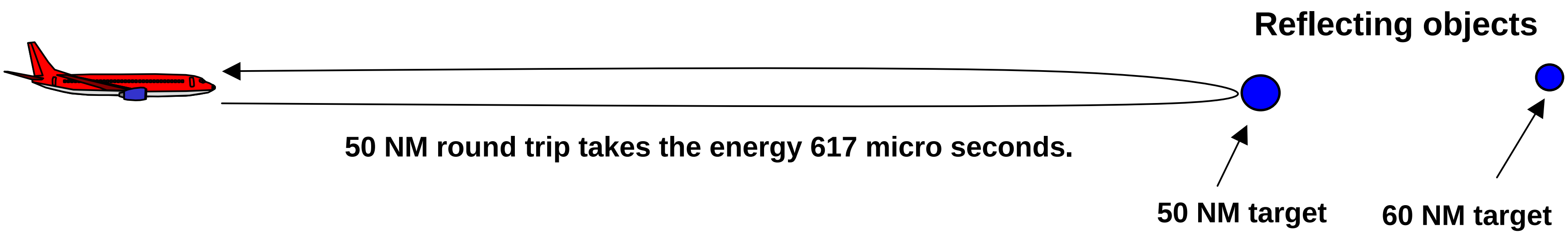
1 nautical mile = 6,076 feet
1 statute mile = 5,280 feet
Speed of light = 186,280 statute miles/second

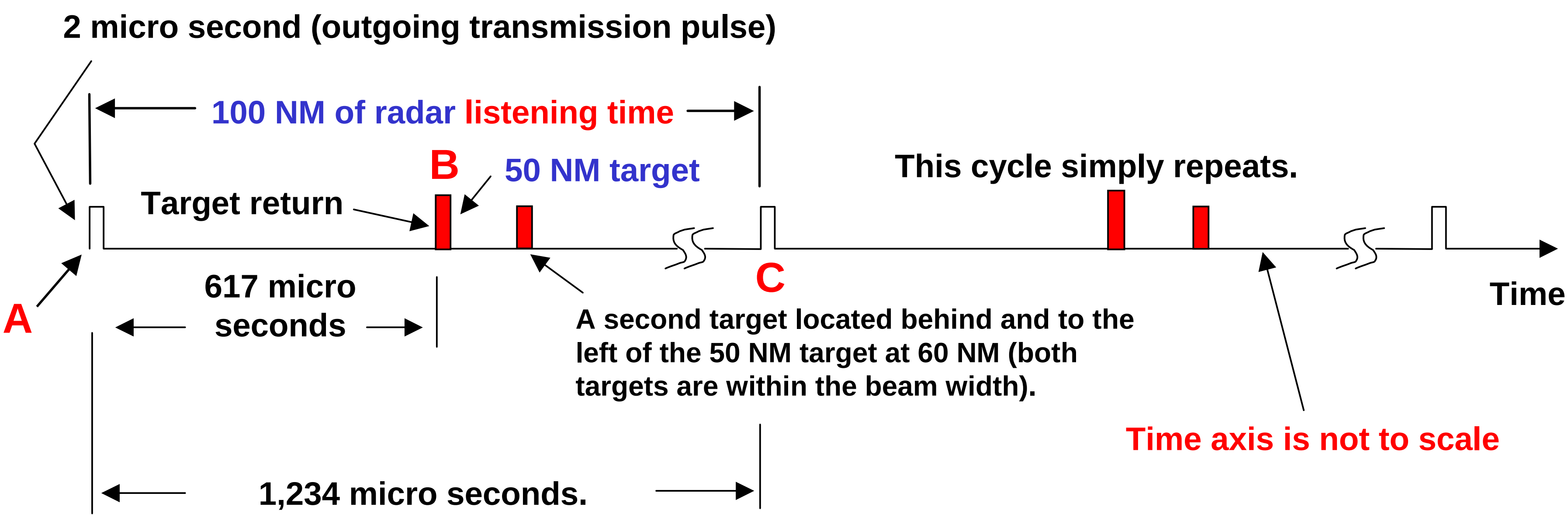
Let's take an example: →

Radar Principles and Operation

(1) Finding the Target's Distance (continued)

Let's say a target is located at 50 NM. The round-trip travel time to the first target is 617 millionths of a second.





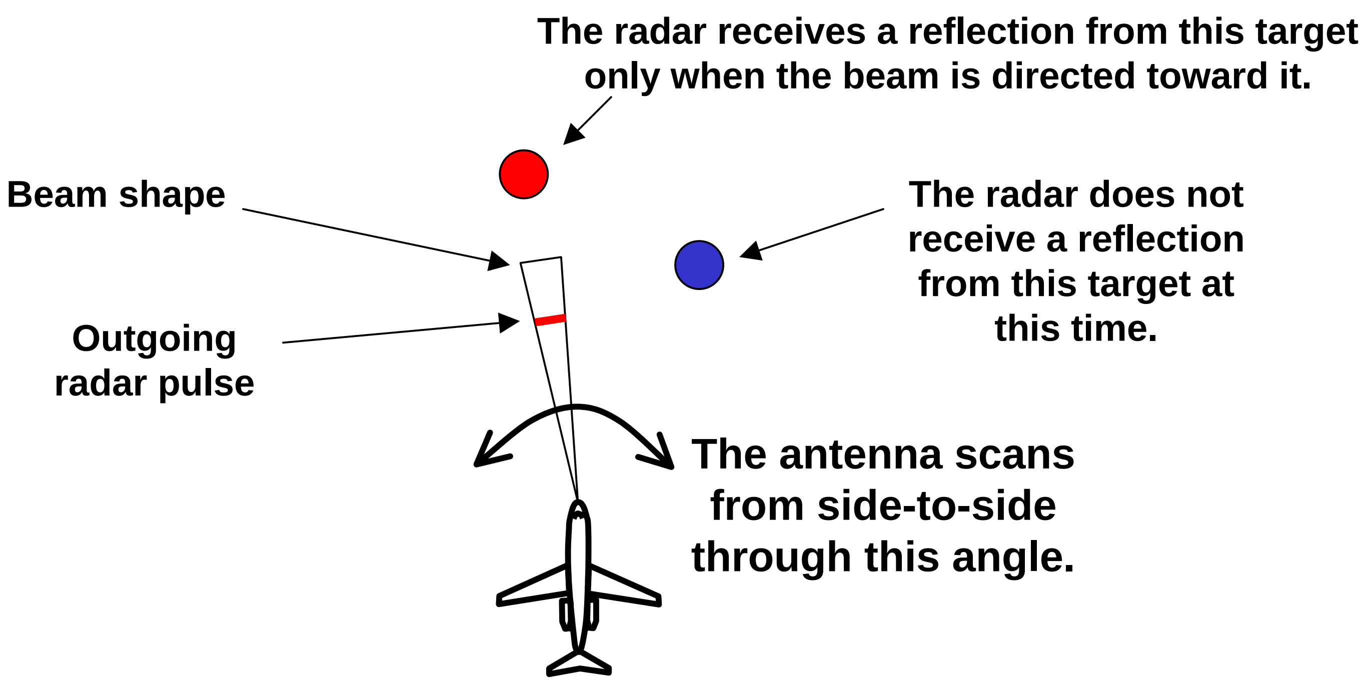
Radar Principles and Operation

(2) Finding the target's direction

The energy radiates from the surface of the antenna in a direction similar to a flashlight's beam.

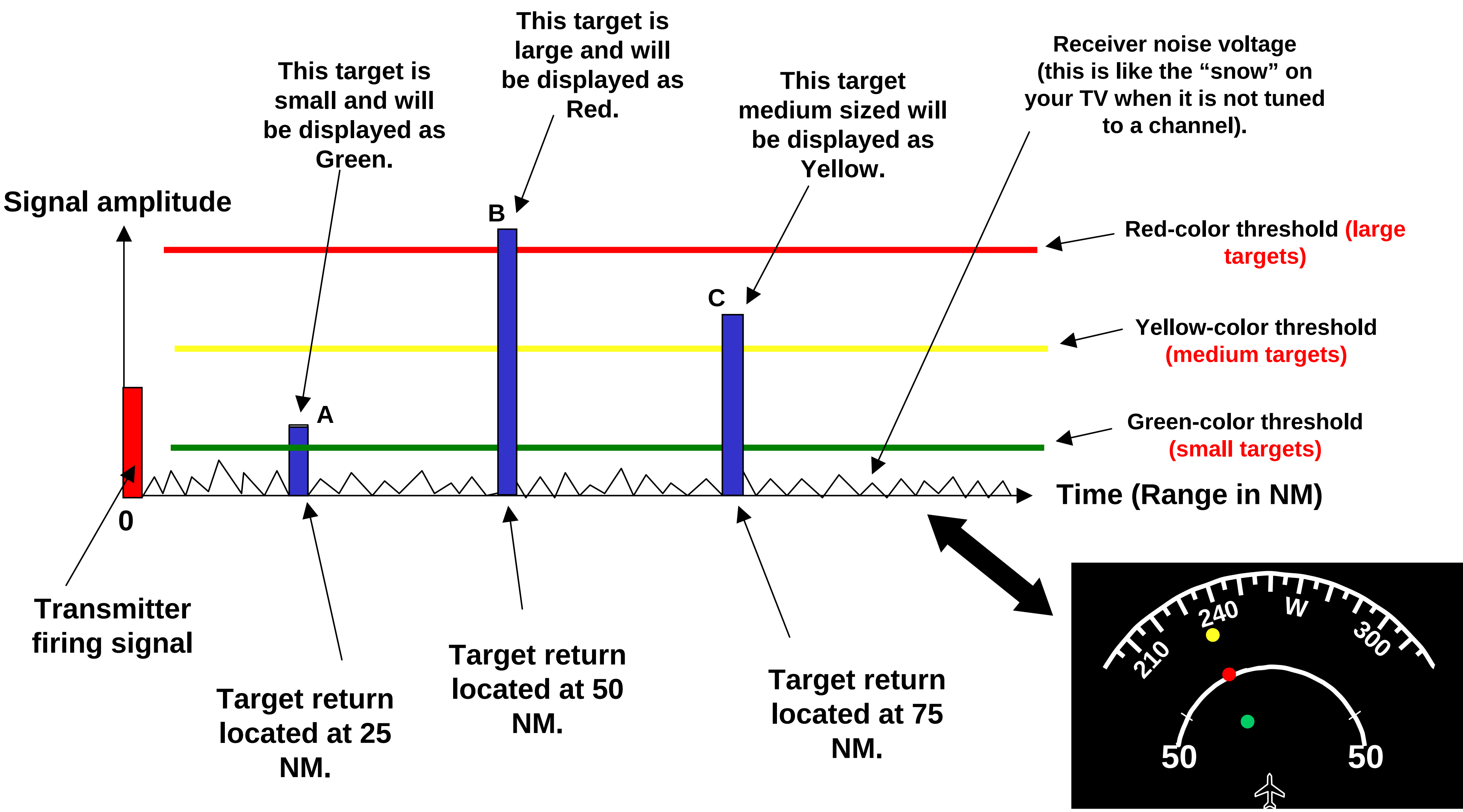
If the antenna is pointed toward a target, the radar will receive a reflection from that target.

Once that occurs, the radar knows the direction to that target.



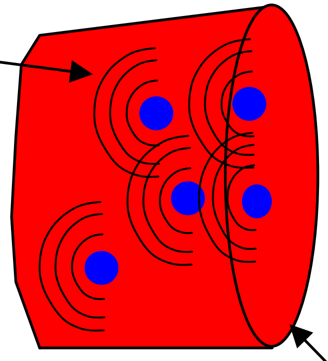
Radar Principles and Operation

(3) Determining the reflection characteristics of the target -- the target’s reflection strength.



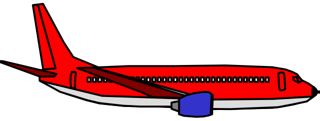
Radar Principles and Operation - Section 1

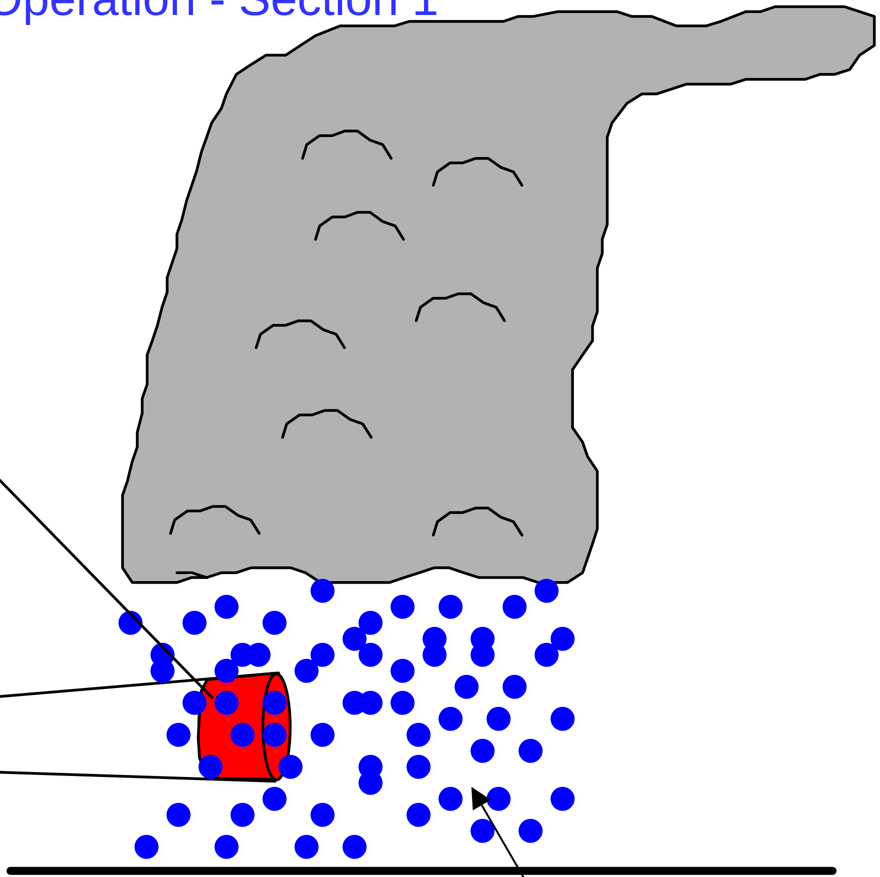
Energy reflection



As you might imagine, it takes a lot of raindrop sized reflections to develop a measurable return signal.

Expanded view of the rain drops reflecting the transmitted microwave energy.

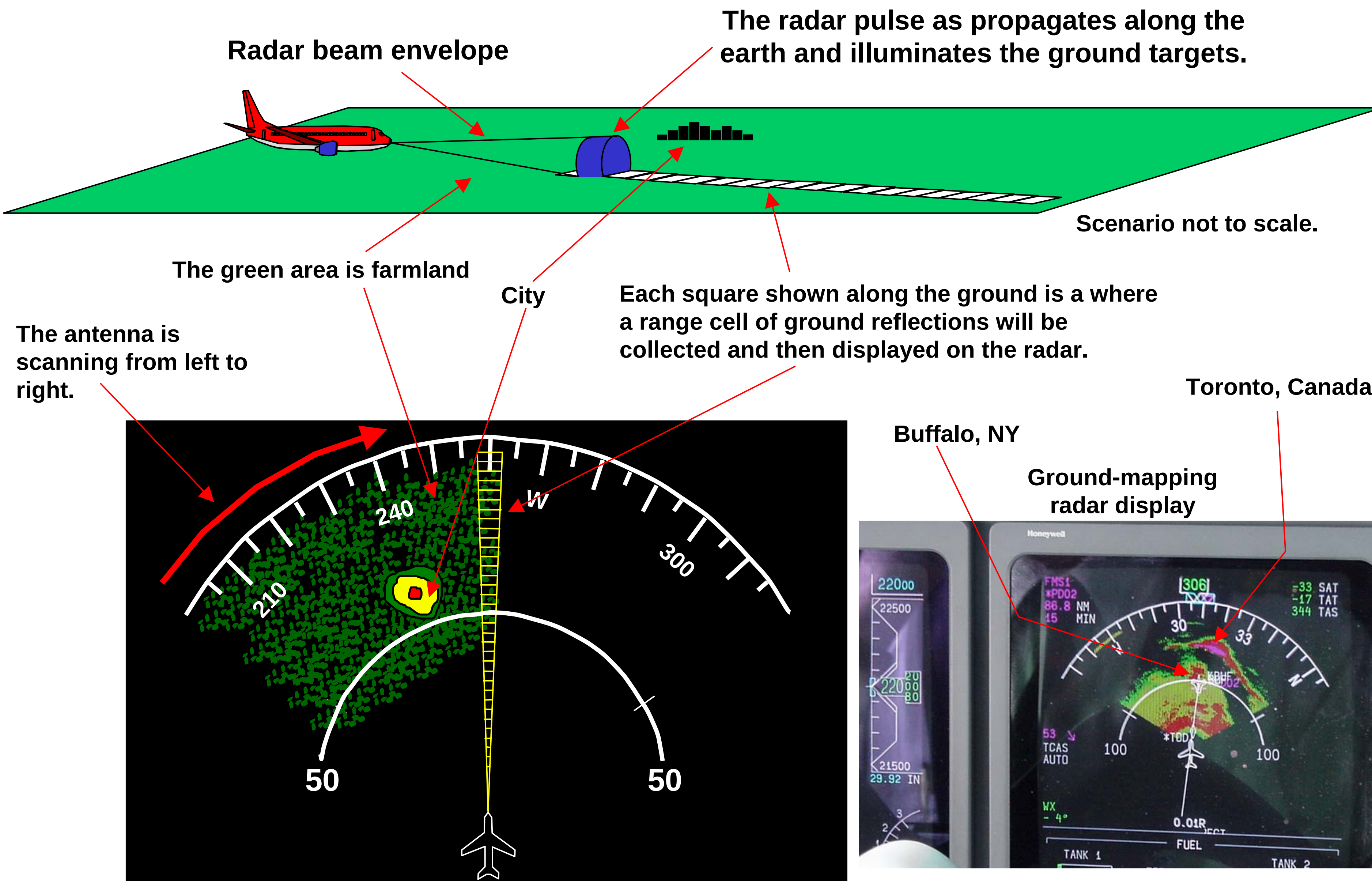




Volumetric-radar target

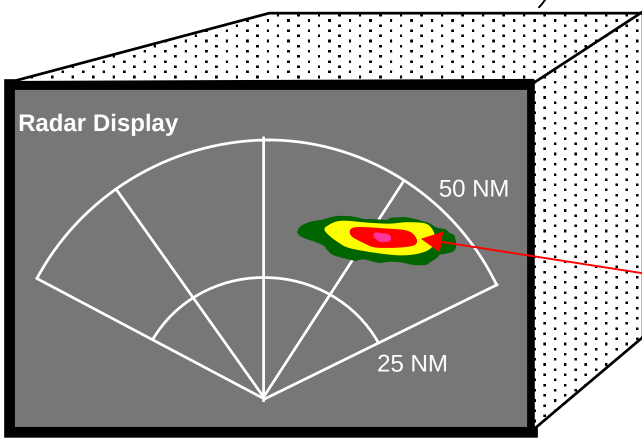
Light rain showers in Kansas.

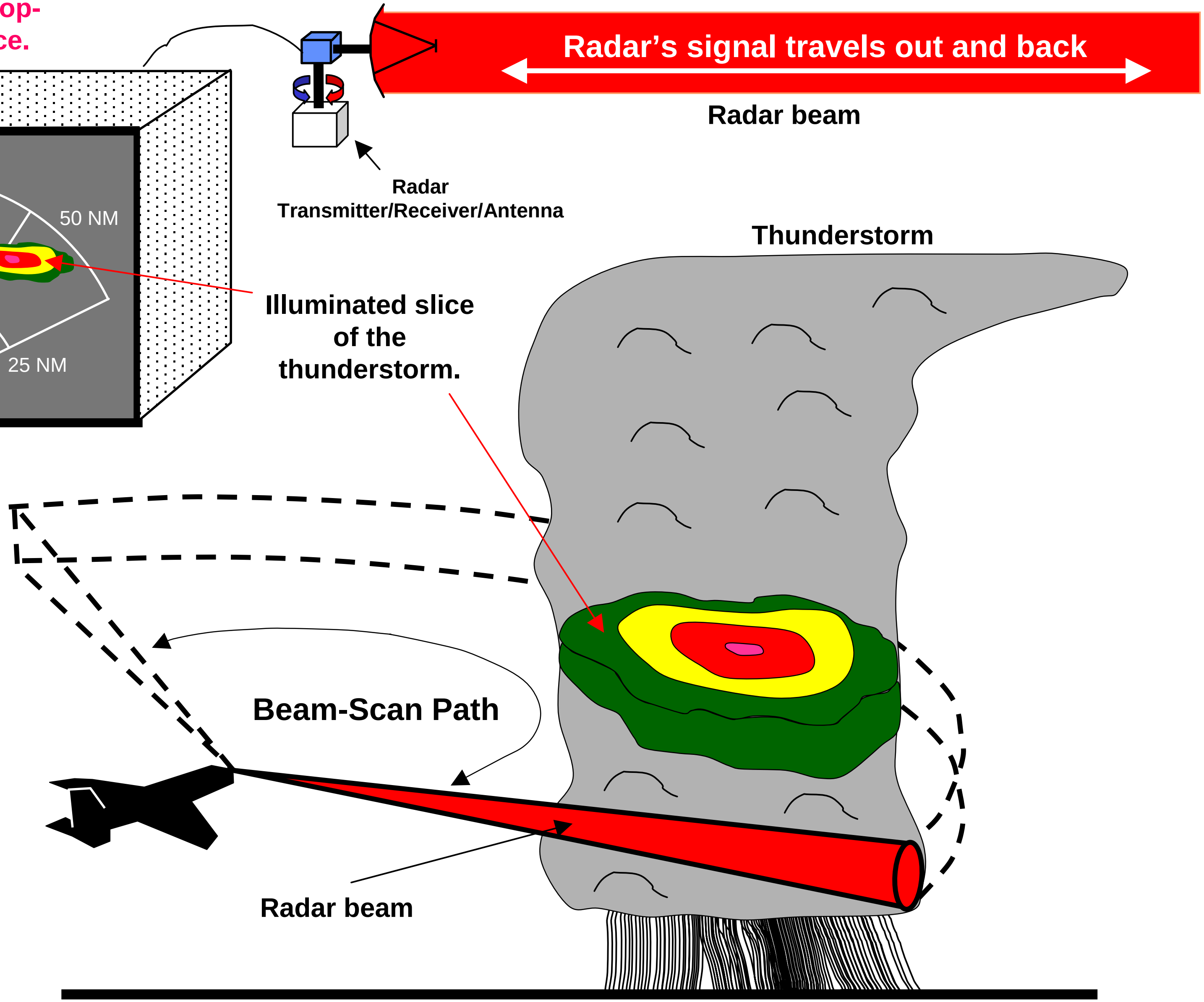
Radar Principles and Operation



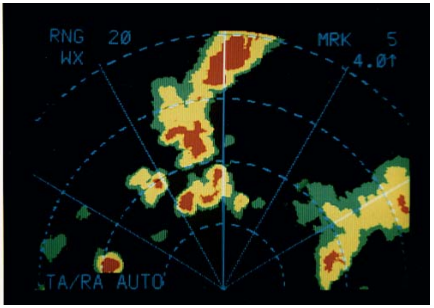
Weather Targets and How They are Displayed

The radar display provides a top-down view of the weather slice.



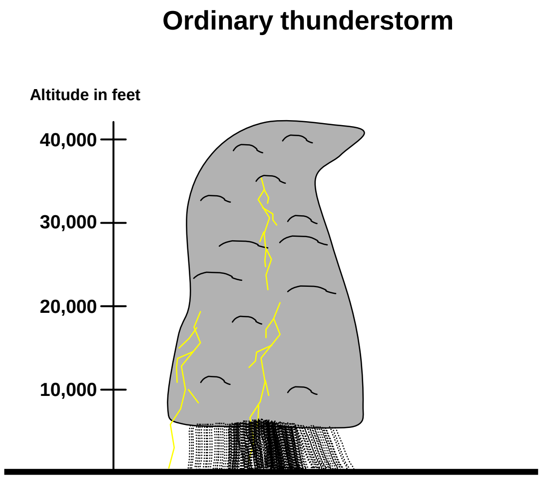


Example of radar display (RDR-4B)



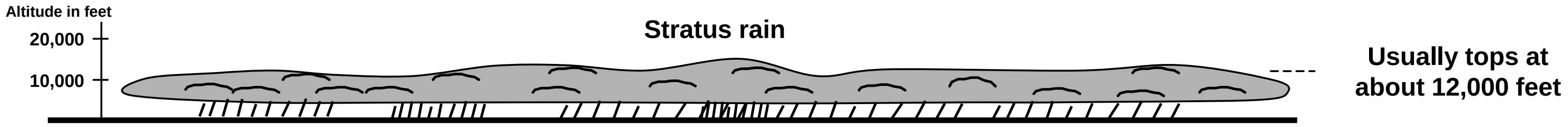
Weather Targets and How They are Displayed

The two most important types of rainstorms are:

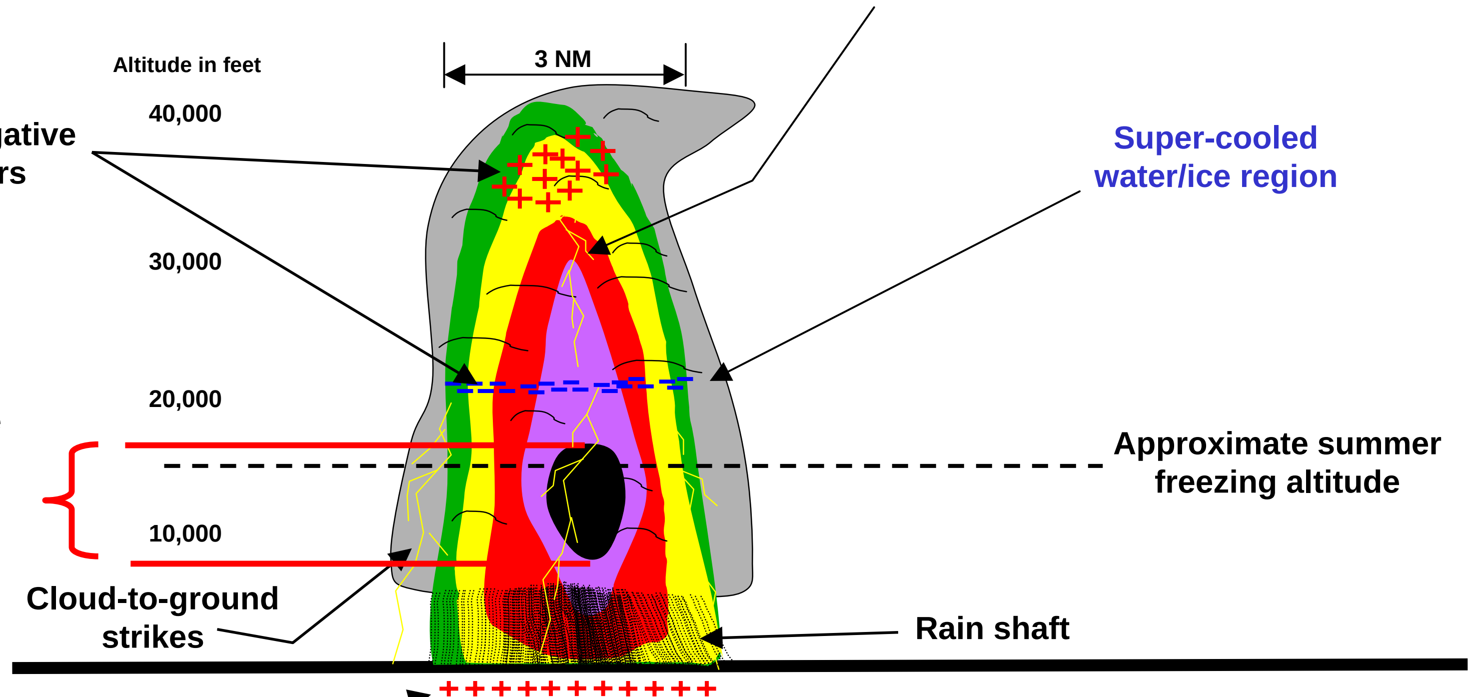


Cumulonimbus (often just called "Thunderstorms")

Stratocumulus (often called "Status" which is low-level extended-rainy weather).



Weather Targets and How They are Displayed



- Extremely heavy precipitation (greater than 8 inches per hour)
- Heavy precipitation (Between 1.91 to 8 inches per hour)
- Heavy precipitation (between 0.45 and 1.91 inches per hour)
- Medium precipitation (between 0.14 and 0.45 inches per hour)
- Light precipitation (between .04 and 0.14 inches per hour)

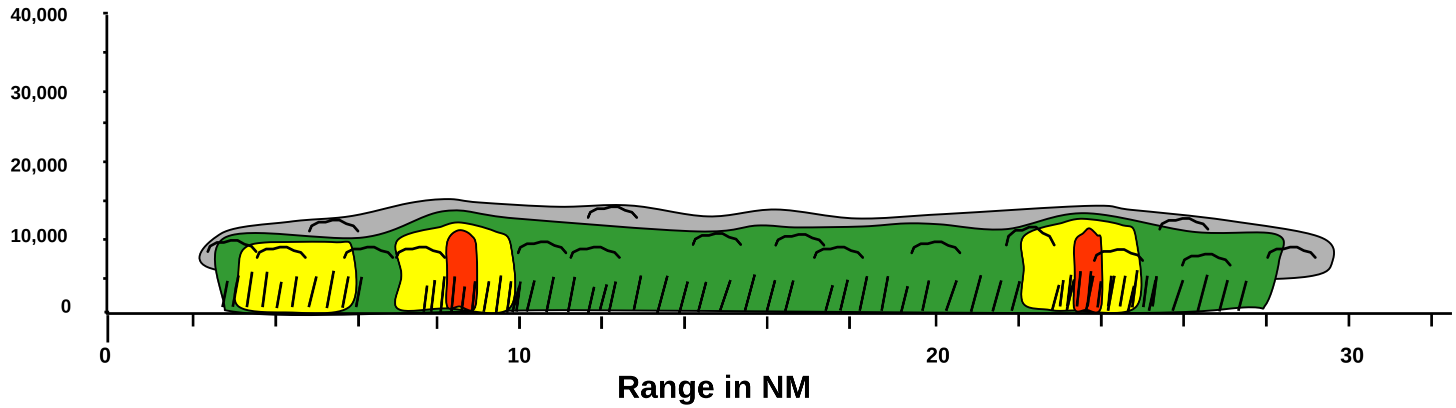
+ Plus electrical charges

— Negative electrical charges

Weather Targets and How They are Displayed

Stratus Rain

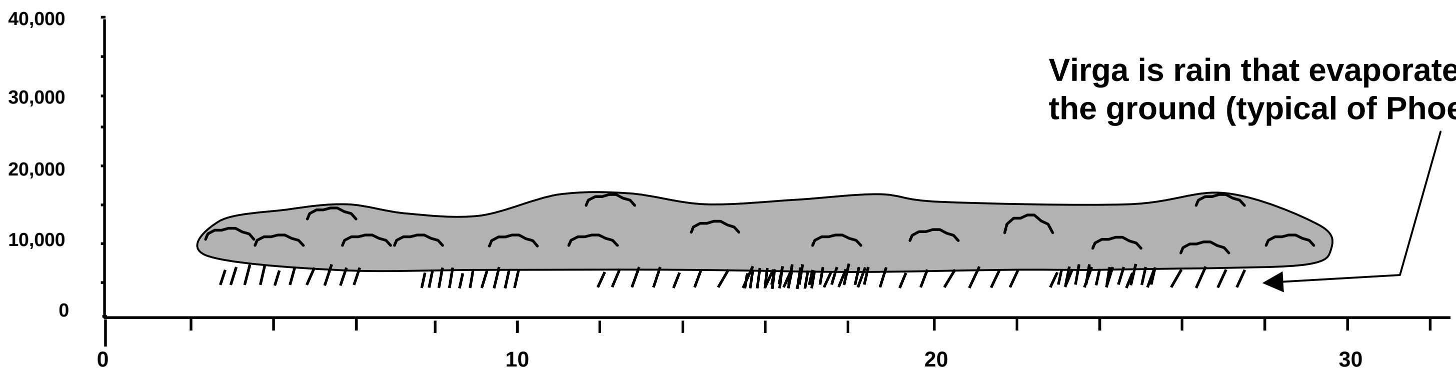
Altitude in Feet



- Heavy precipitation (greater than 1.91 inches per hour)
- Heavy precipitation (0.45 to 1.91 inches per hour)
- Medium precipitation (between 0.14 and 0.45 inches per hour)
- Light precipitation (between .04 and 0.14 inches per hour)

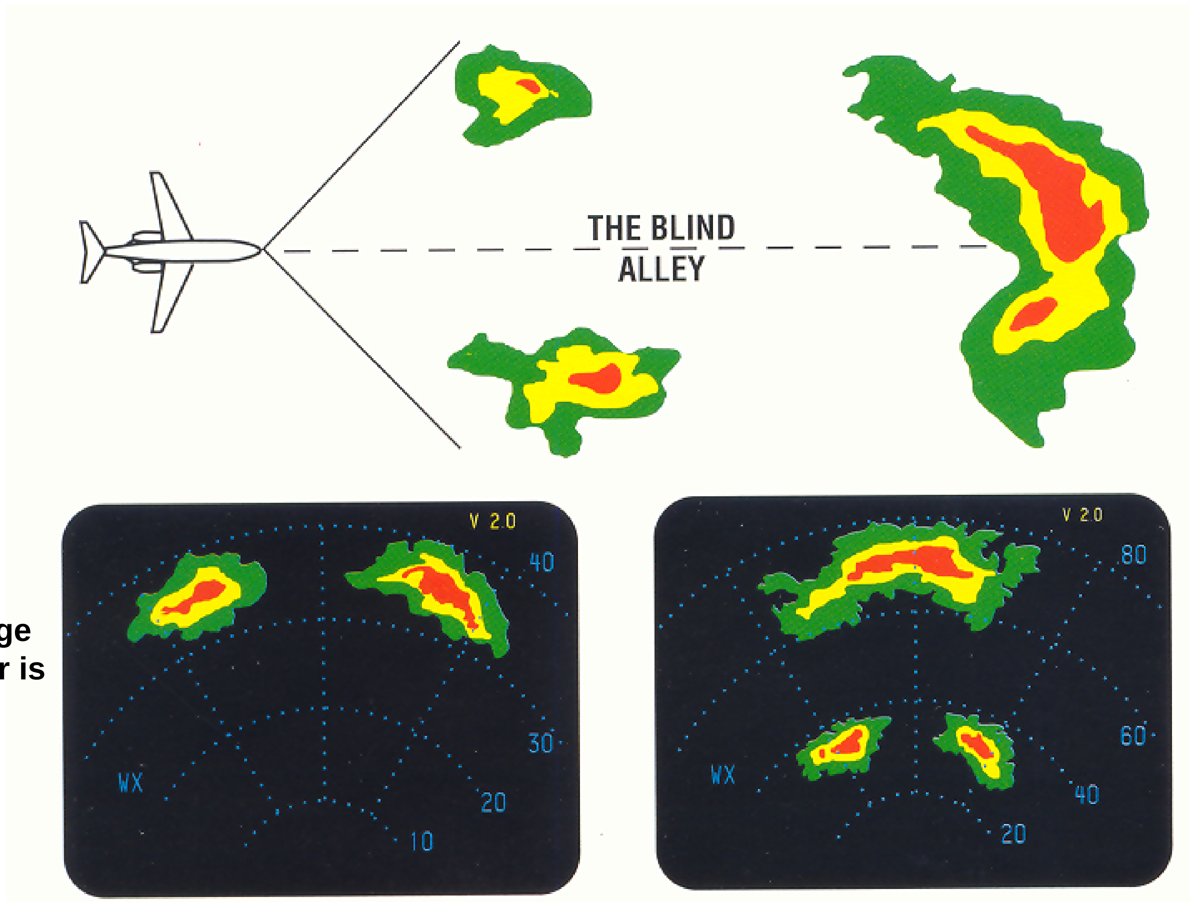
Altitude in Feet

Virga is rain that evaporates before it reaches the ground (typical of Phoenix, AZ).



Weather Targets and How They are Displayed

When using the weather radar, always beware of a "Blind Alley" or "Box Canyon" situation. The diagram below depicts just such a flight scenario:



Short Range

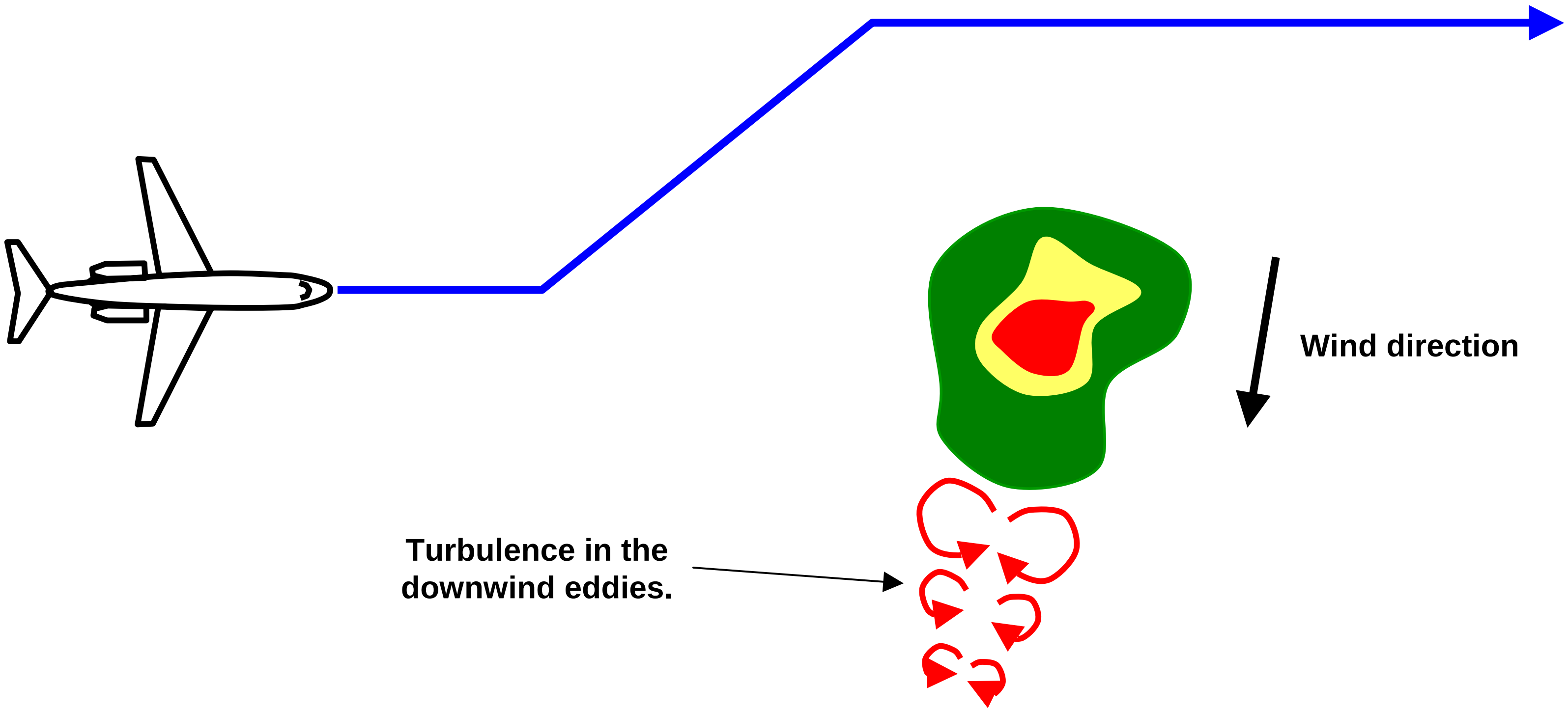
Longer Range

On the 40 NM range the weather danger is not evident.

The 80 NM range provides much better situational awareness.

Weather Targets and How They are Displayed

Whenever possible, deviate to the upwind side of a storm to avoid the downwind eddy currents. These eddies are caused by the obstruction the storm presents to the wind stream.



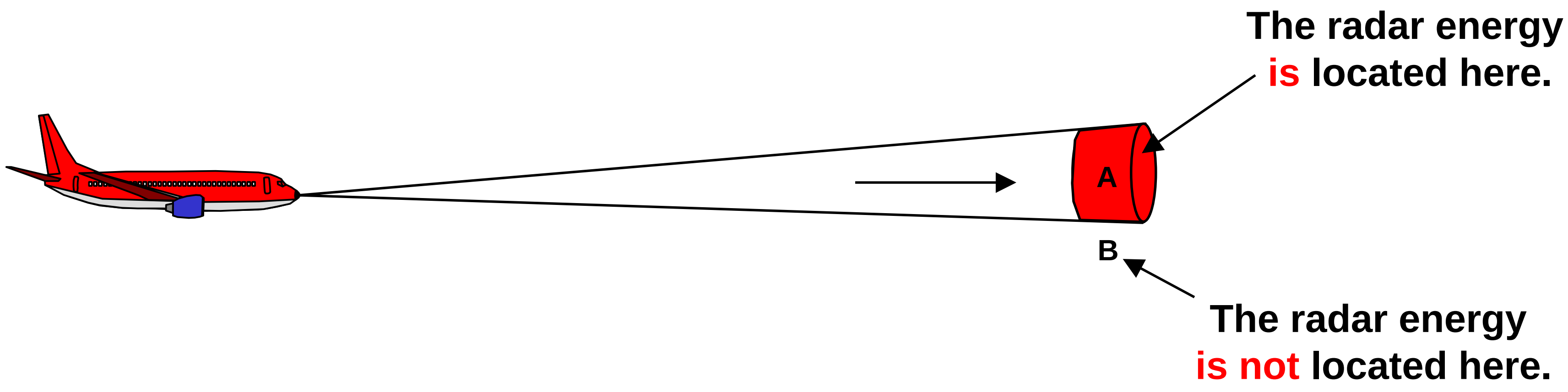
Before we proceed further, we need to discuss some key concepts:

- **The true nature of the radar's radiated beam.**
- **The definition of a "calibrated-weather".**
- **The Weather Attenuation phenomenon, and how to use it to your advantage.**
- **The introduction of the "Radar Tilt-Angle Calculator".**
- **The Tilt Management procedure.**
- **How to deal with Stratus Rain.**

Knowing these concepts and using the Radar Tilt-Angle Calculator will enable you to make informed decisions about how to properly use a weather radar.

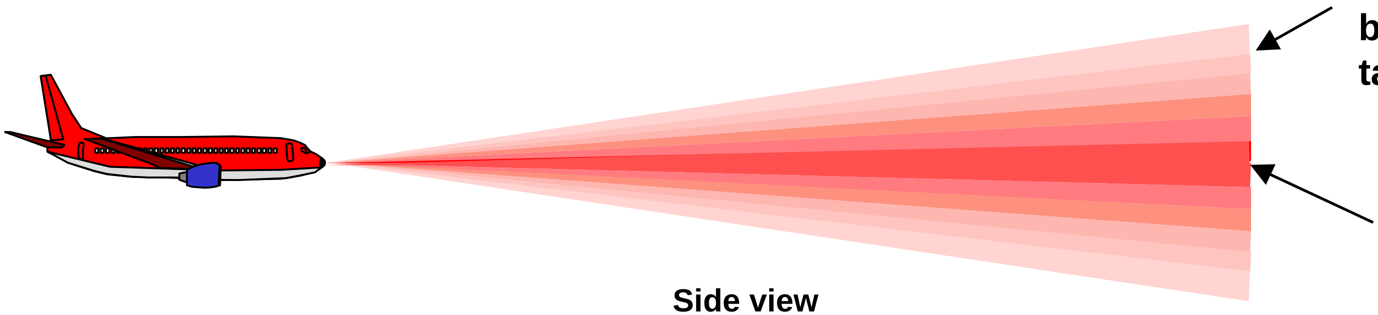
The Radiated Beam Width

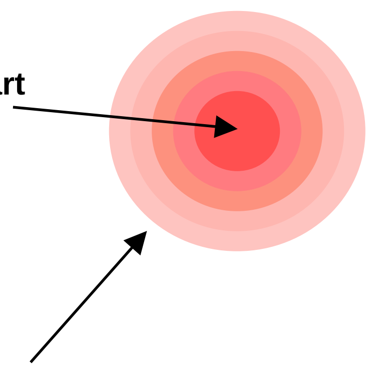
Generally, we consider the radar beam as being cone shaped.



The Radiated Beam Width

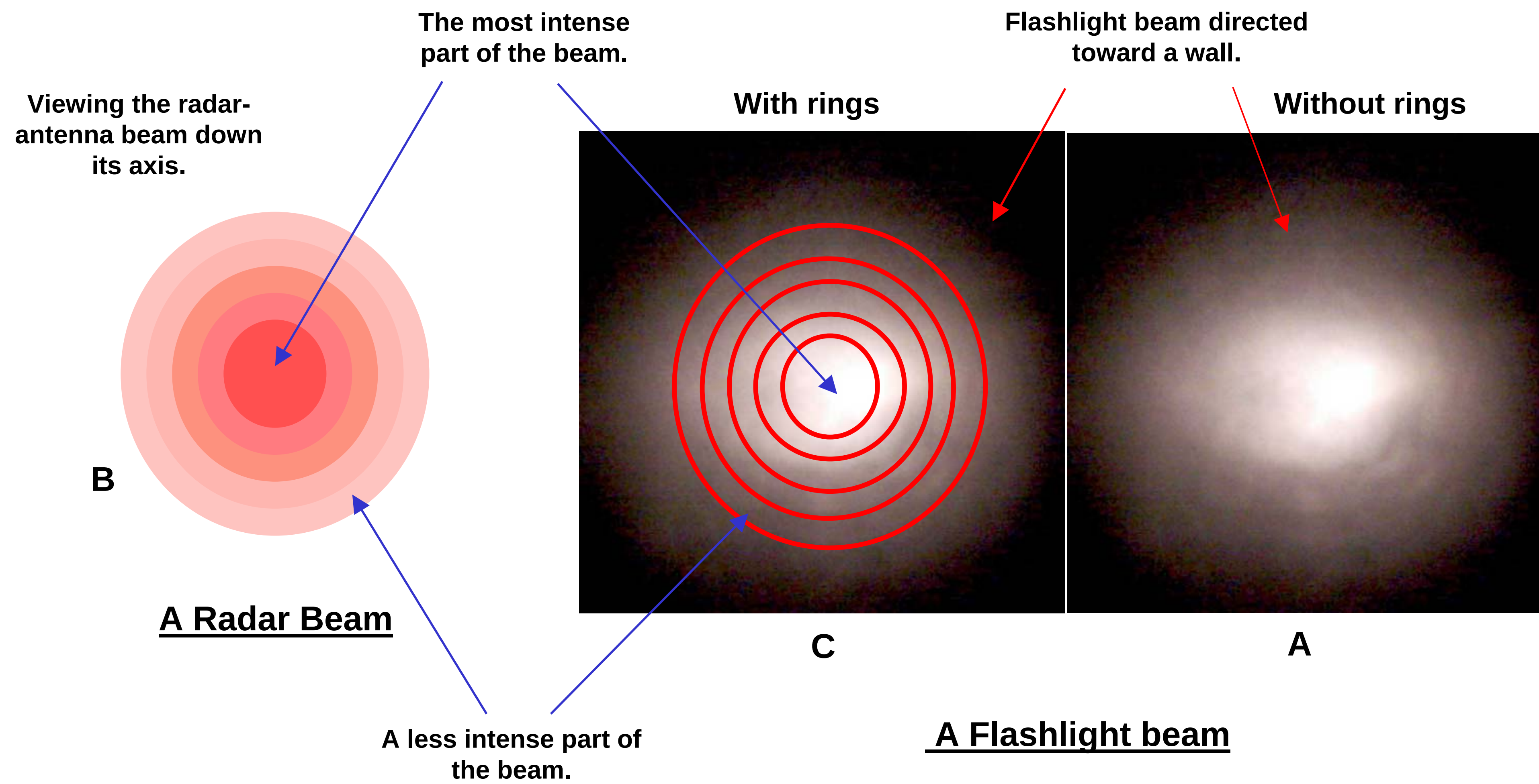
The diagram below is a better representation of how energy actually radiates from a radar's antenna:





Now let's use a flashlight's beam to further clarify the concept:

The Radiated Beam Width

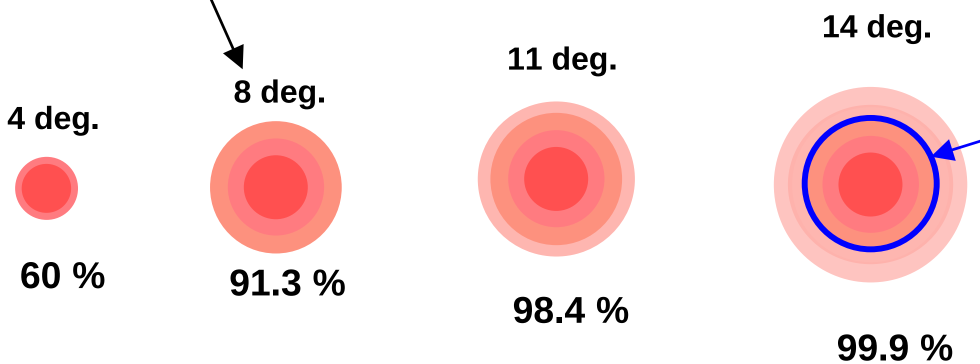


A radar's beam and a flashlight's beam are both examples of focused electromagnetic energy. Their radiation characteristics are identical!

The Radiated Beam Width

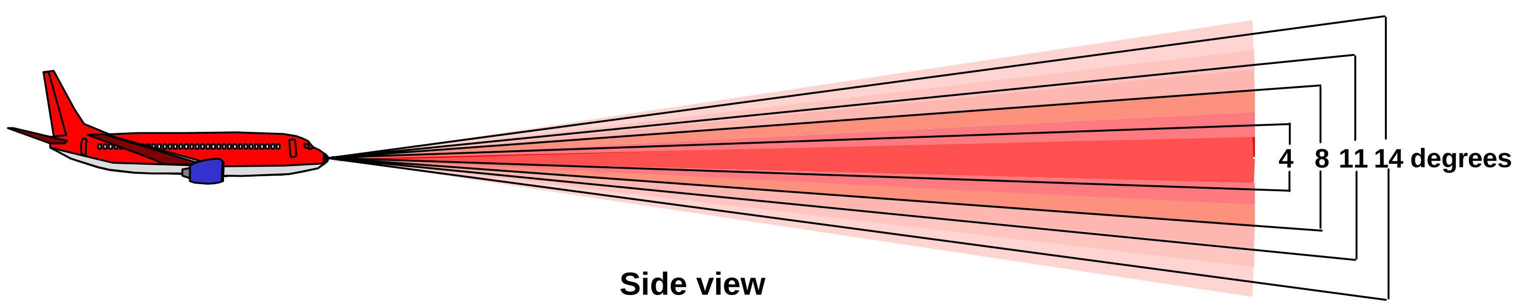
Below is shown how much of the energy, in percent, is contained within various cross sections of the radar's beam width for a 12" antenna:

This is the advertised beam width of the antenna. That is also what we will later refer to as the Weather-Detection Beam Width.



You will see that the most reflective part of weather targets should be viewed using the inner core of the beam width. Unfortunately, the outer 'spread' will also "scoop-up" unwanted ground clutter.

End view



Side view

The Radiated Beam Width

The Antenna-Gain concept:

You may have heard the term: Antenna Gain

This term is somewhat misleading. It sounds as though the microwave energy enters the antenna and is somehow increased before leaving it.

That interpretation of Antenna Gain are incorrect!

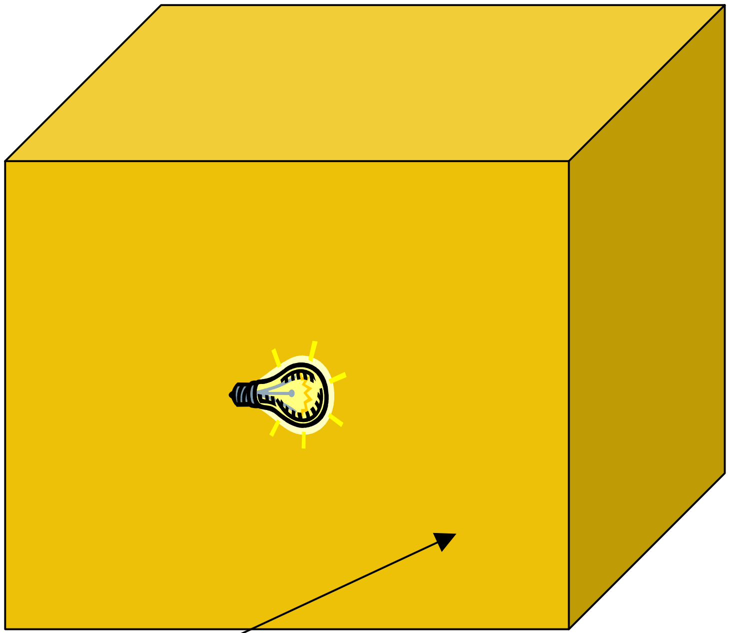
The term Antenna Gain describes how much the energy leaving the antenna is focused into a particular direction.

Let's take a couple of examples:

The Radiated Beam Width

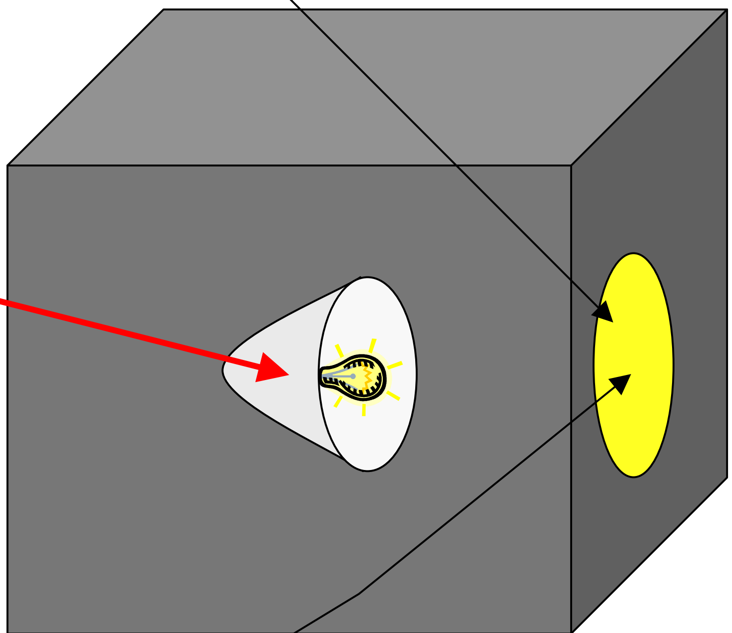
In this room, the light is spread evenly over the walls.

In this room, the light is now concentrated into a spot on one wall.



A

Here we added a reflector to the same bulb. This reflector/light bulb combination is a focused antenna system.



B

The ratio of the focused-light intensity of the spot on this wall to the average intensity of light on these walls is the antenna system's gain.

$$\text{Antenna Gain} = \frac{\text{Focused Intensity}}{\text{Average Intensity}}$$

The Radiated Beam Width

The key takeaways from this discussion on beam shapes are:

- **To maximize the signal return from a weather target, it should be observed through the center of the beam where the highest level of energy is located (or at least within the advertised beam width for that antenna). That beam width for the 30-inch antenna is 3.0 degrees, for the 24-inch antenna is 4.5 degrees and for 12-inch it is 8.0 degrees.**

- **.**

- **Ground targets, can and will be observed at angles considerably off the antenna beam axis because they are strong reflectors (especially cities).**

The Concept of a Calibrated-Weather-Radar Presentation:

Definition of Calibrated weather:

A thunderstorm will maintain its accurate color-code presentation on the radar's display regardless of its range -- or more realistically, to the limits of the radar's capability.

Generation of calibrated weather requires three things:

1. **A reference thunderstorm.**
2. **A way to compensate for "space loss".**
3. **A way to compensate for the "beam-filling" effect.**

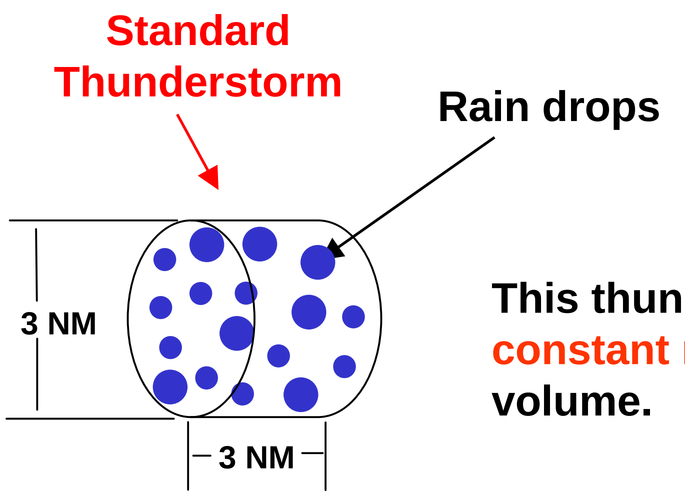
Concept of Calibrated Weather

In order for the airborne-weather-radar industry to be able to calibrate their systems, they needed to have a reference thunderstorm.

After considerable thunderstorm-size evaluation, they decided the following storm model would be appropriate:

The calibrated rain-rate colors:

- **Heavy precipitation (greater than 1.9 inches per hour)**
- **Heavy precipitation (between 0.45 and 1.9 inches per hour)**
- **Medium precipitation (between 0.14 and 0.45 inches per hour)**
- **Light precipitation (between .04 and 0.14 inches per hour)**



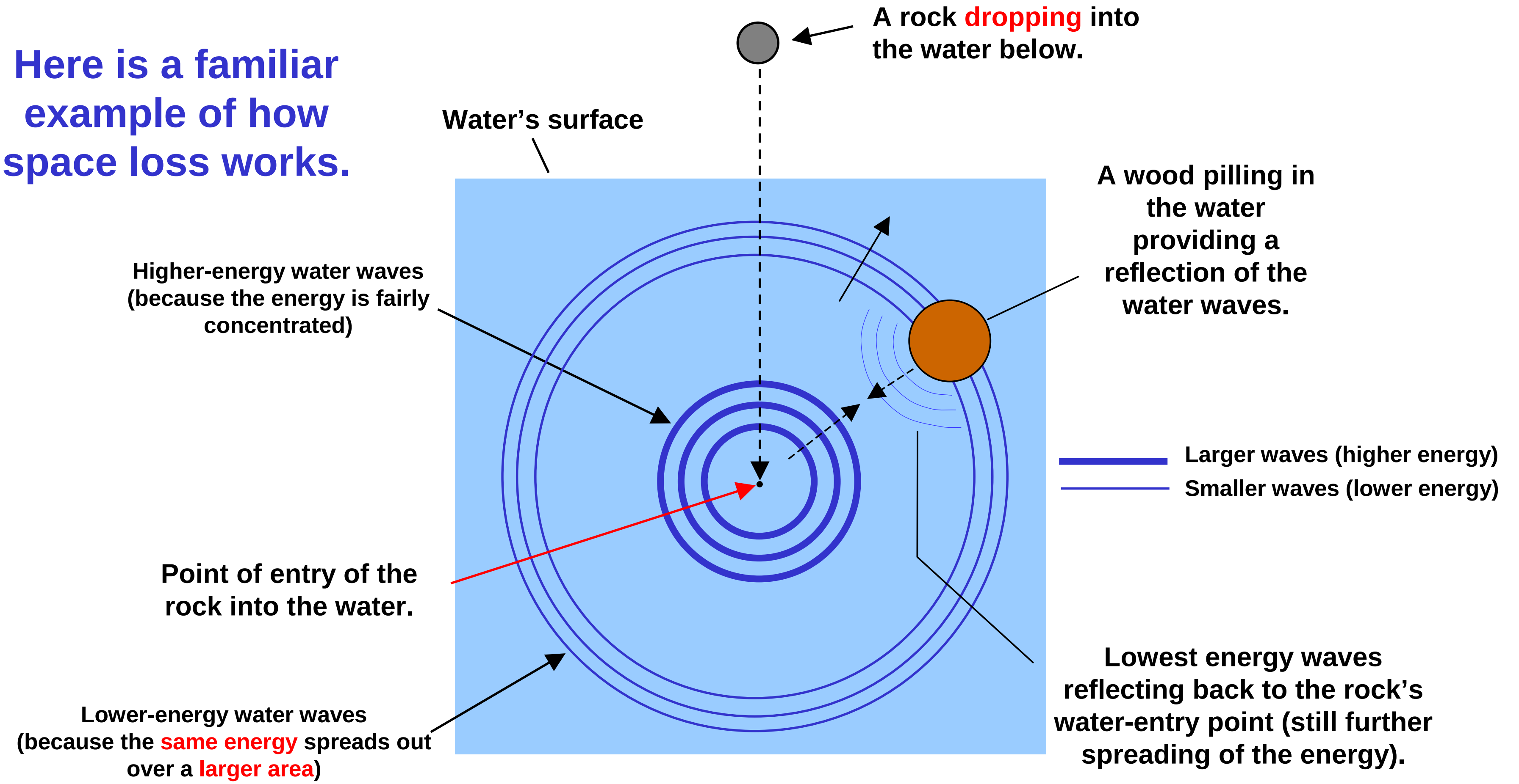
This thunderstorm model has a constant rain-rate throughout its volume.

Now that we have a rainstorm reference, next we need to consider the effects of space loss:

Concept of Calibrated Weather

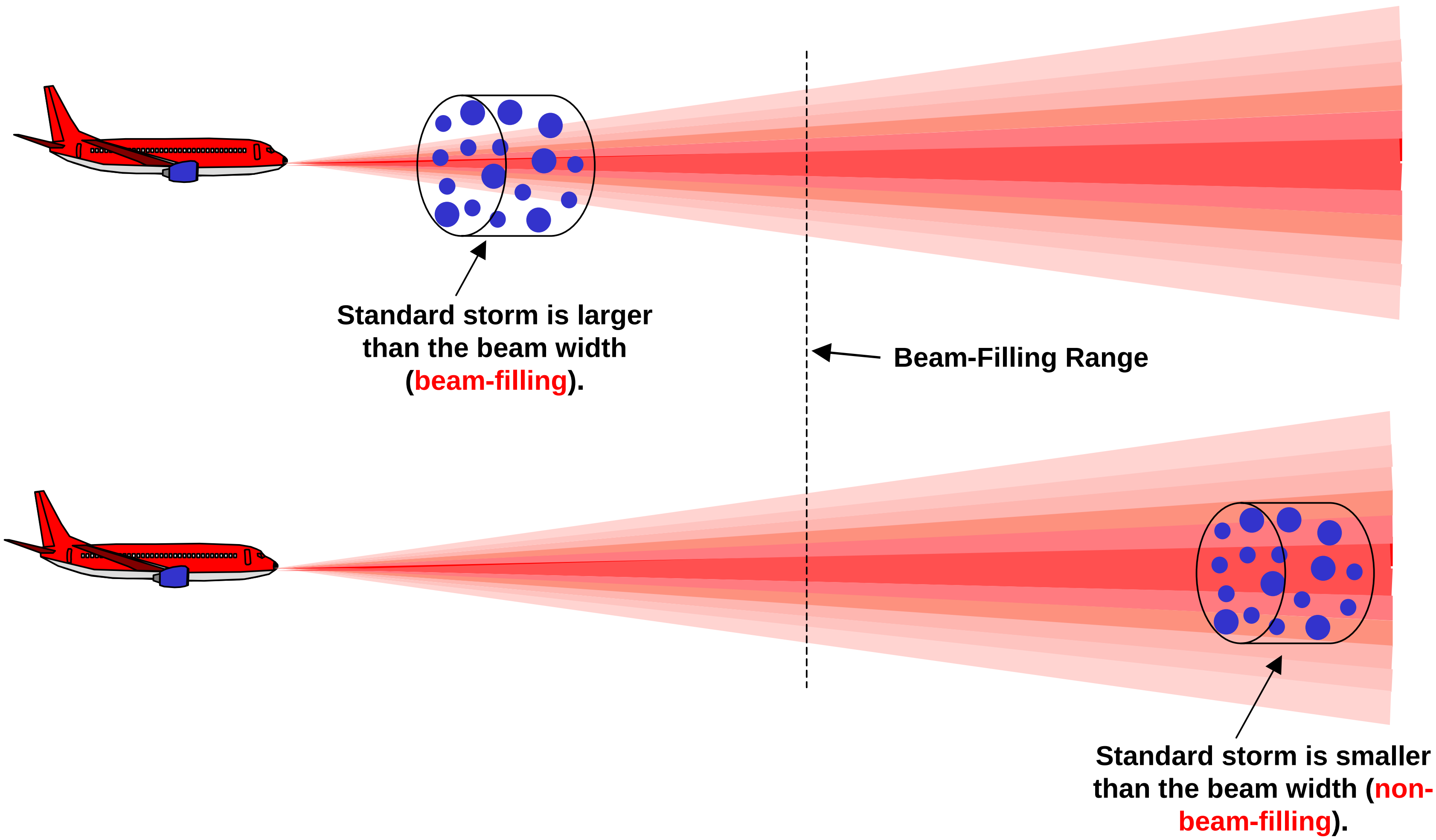
Definition of Space Loss: As the radar's microwave pulse travels to and from a target, most of its energy is simply not retrievable. That is because the energy simply goes into directions other than where the target and radar are located. The same phenomenon occurs at the same rate for both "focused" and "non-focused" energy propagation.

Here is a familiar example of how space loss works.



Concept of Calibrated Weather

Beam-filling Phenomenon:



The radar compensates for both the space loss and the effects of beam-filling producing a constant color coded storms regardless of their range (within limits). It does this using an approach called "Sensitivity-Time-Control (STC)".

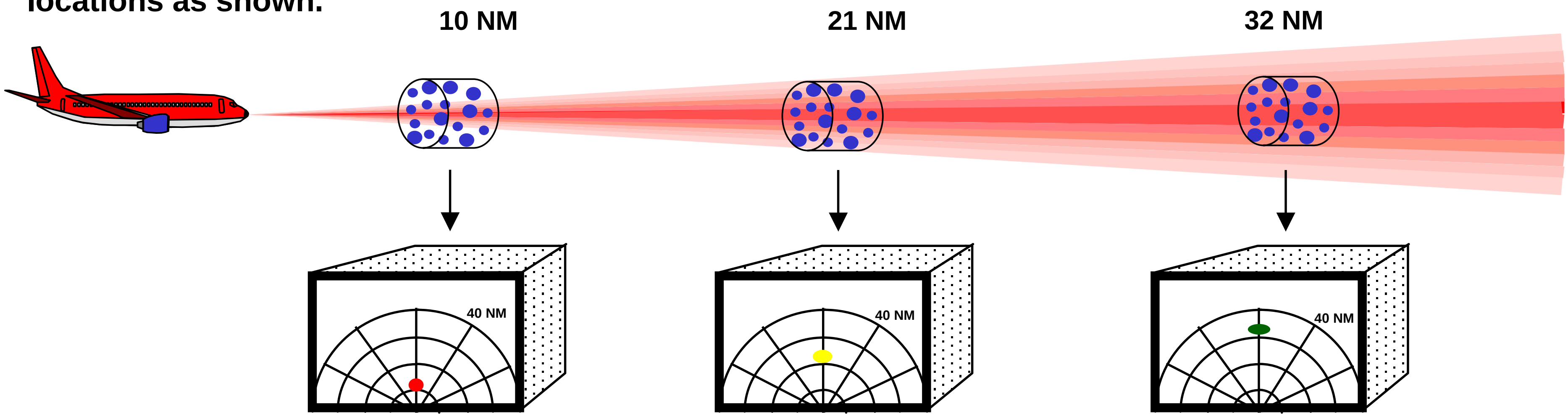
That means the radar adjusts the levels of its color thresholds to effectively cancel out both of these effects.

Here's an example: →

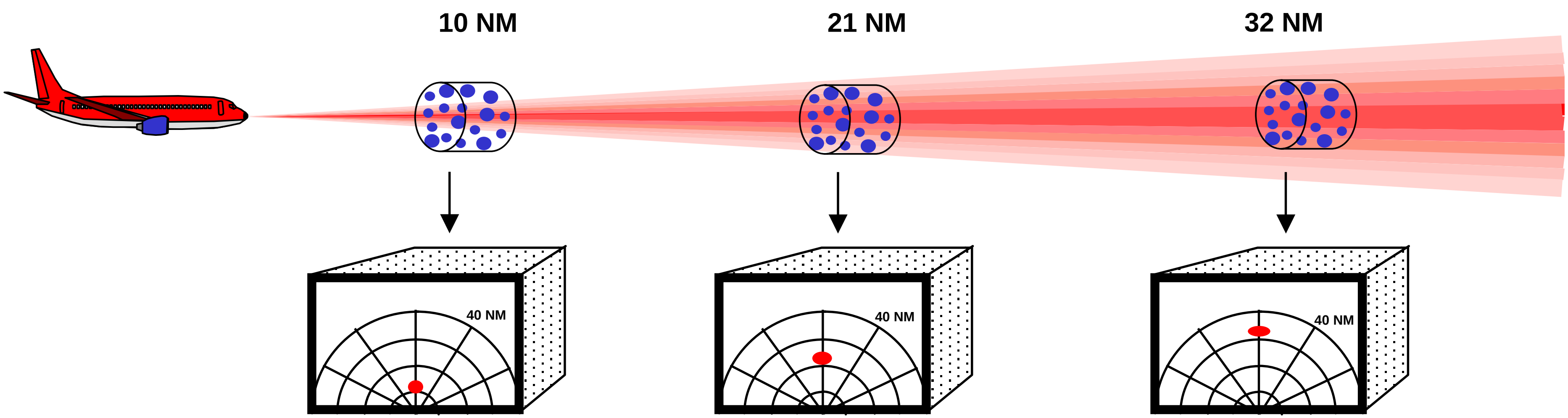
Let's say this red level storm is moved to three different range locations as shown.

Concept of Calibrated Weather

Without STC



With STC

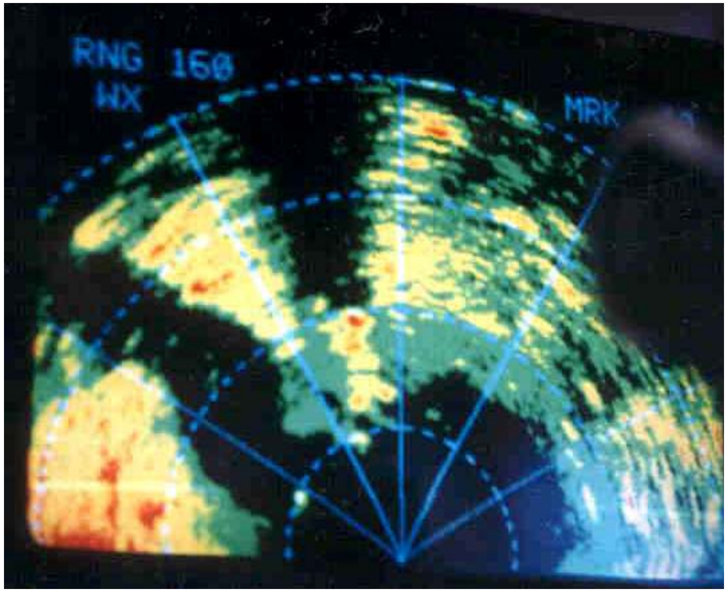


Weather Attenuation

Sometimes it is hard to identify the true nature of a target on a radar.

That can certainly be the case trying to differentiate between thunderstorms and cities.

Here are a couple of examples:



Cities and thunderstorms are present in both radar presentations.

Weather Attenuation

As it turns out, thunderstorms have a characteristic that allows us to identify them on the radar screen:

It's called Weather Attenuation.

The radar pulse loses some of its strength as it travels through the core of a thunderstorm!

That turns out to be very helpful for finding dangerous weather.

Let's take a closer look at this phenomenon:

Weather Attenuation

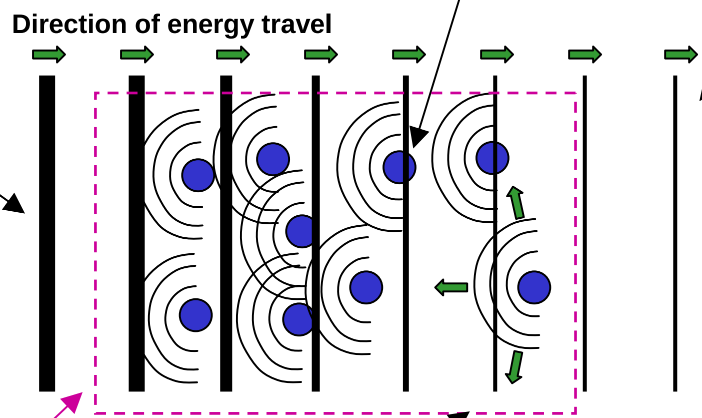
1

The incoming microwave energy from the radar is represented by vertical bars. The bar's thickness indicates the incoming signal's strength.

Raindrop

The signal's strength that exits the rain area can be significantly reduced if the rainstorm is strong.

3

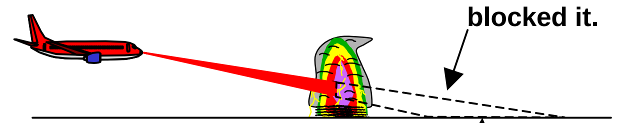


This is the shadowed area directly behind the dangerous storm.

This represents a small section of the rainstorm.

2

The beam would have been here but the storm blocked it.



This ground is not illuminated so there is a radar shadow on the display.

You can see that each raindrop "scatters" some of the incoming signal into random directions. Some of this "scattered" energy will be returned to the radar. Most of it will simply be lost.

Lets' see how much of the radar's signal the storm can eliminate?

Weather Attenuation

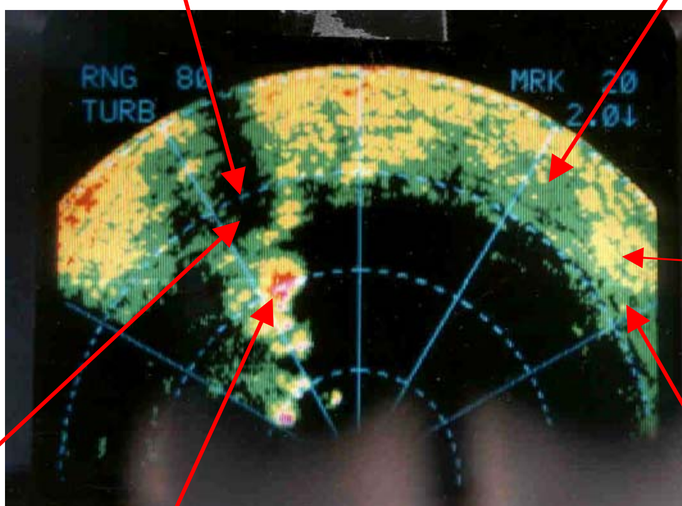
The stronger the rainstorm, the more radar energy will be scattered by Weather Attenuation.

Here are two examples:

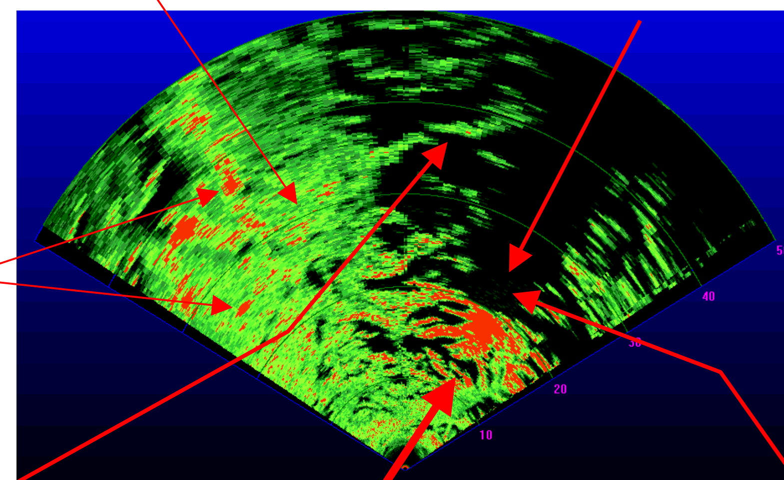
Ground returns (also called "ground clutter").

A radar shadow caused by weather attenuation.

A radar shadow caused by mountain attenuation.



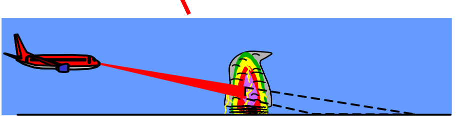
Cities (notice there is no radar shadow)



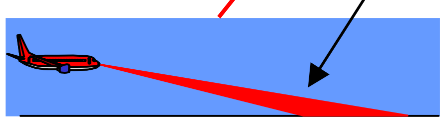
A dangerous thunderstorm is located forward of the radar shadow.

Mount Rainier in Washington state (14,406 feet tall)

A dangerous mountain is located forward of the radar shadow.

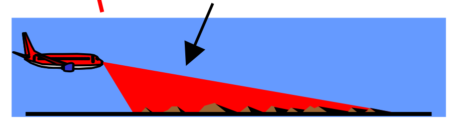


Thunderstorm Radar shadow



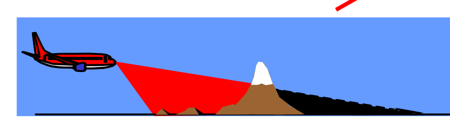
Pencil beam

Flat terrain



Fan beam

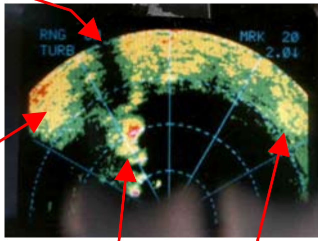
Mountainous terrain



Tall mountain Radar shadow

Weather Attenuation

Radar shadow



City

Here is a two-part technique for finding dangerous-weather:

1 **First, display plenty of ground returns on your radar and look for an "apparent" radar shadow,**

and then,

2 **look forward of the shadow to see if a storm is present (or a very tall mountain).**

Tip: Rainstorms and tall mountains cast radar shadows. Cities do not!

This is an extremely important point!

Weather Attenuation

Now let's look at those weather presentations again.

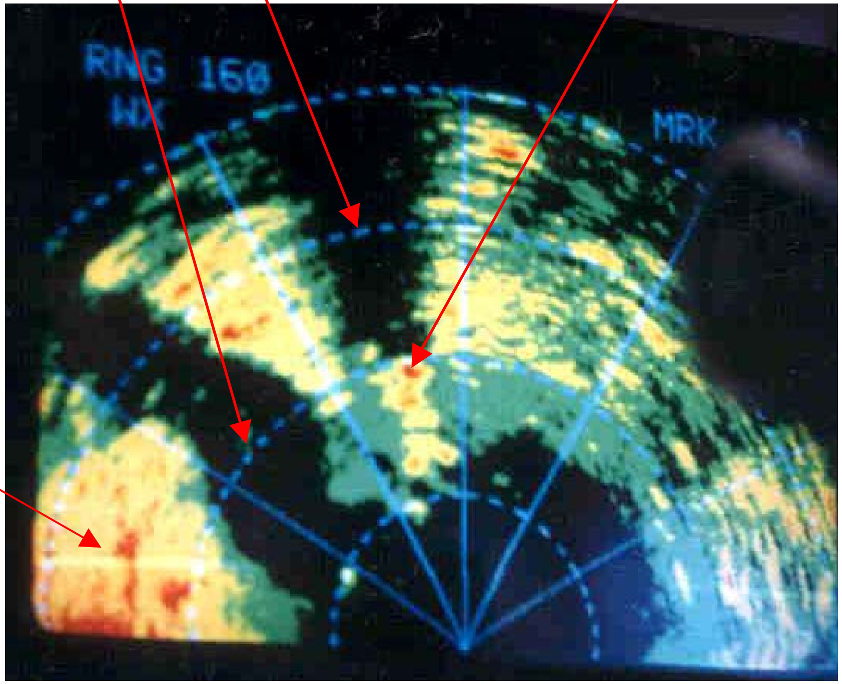
First look for the potential shadows. (1)
Then,
look for a thunderstorm in front of the shadow. (2)

Potential Radar shadow (but it's not). This is probably one of the great lakes.

Potential Radar Shadow (it is)

Thunderstorm

City



Potential Radar Shadow (it is)

Thunderstorm

City (no shadow)

Weather Attenuation - Section 3

Here is a picture of a dangerous thunderstorm taken in an ERJ-145 aircraft equipped with a Honeywell Primus 660 Weather Radar. This radar picture below demonstrates the correct procedure for evaluating a storm as you will see next.

Ground clutter (a good thing)

Here is a Radar Shadow caused by weather attenuation. This V-notch shaped radar shadow behind a thunderstorm is the display characteristic you should always be attempting to identify.

Thunderstorm

These light targets shown inside of the shadowed area are very strong ground reflectors (cities). While not completely disappearing, their reflection has been significantly reduced due to the storm's weather attenuation.

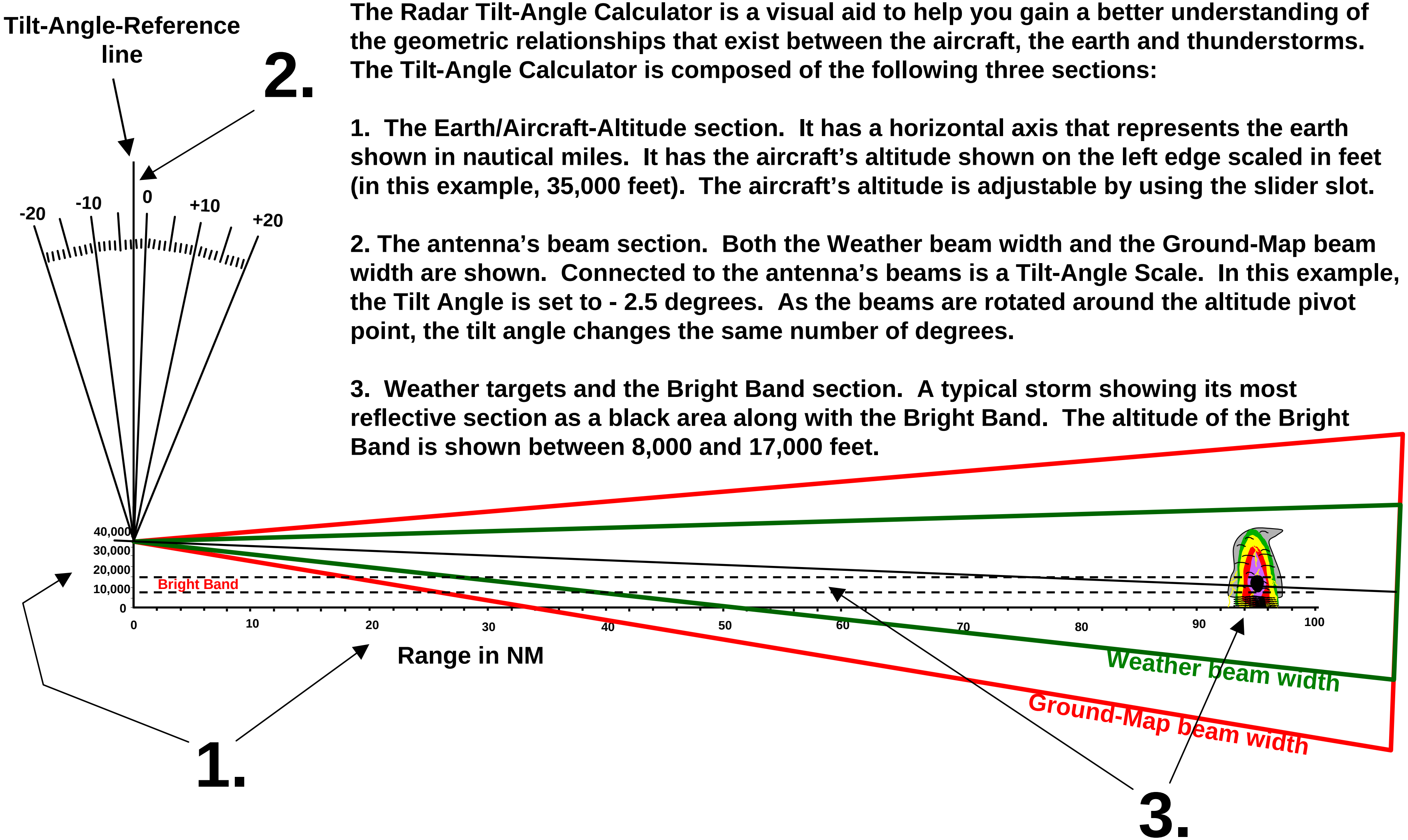
Radar Tilt-Angle Calculator

The Radar Tilt-Angle Calculator is a visual aid to help you gain a better understanding of the geometric relationships that exist between the aircraft, the earth and thunderstorms. The Tilt-Angle Calculator is composed of the following three sections:

1. The Earth/Aircraft-Altitude section. It has a horizontal axis that represents the earth shown in nautical miles. It has the aircraft's altitude shown on the left edge scaled in feet (in this example, 35,000 feet). The aircraft's altitude is adjustable by using the slider slot.

2. The antenna's beam section. Both the Weather beam width and the Ground-Map beam width are shown. Connected to the antenna's beams is a Tilt-Angle Scale. In this example, the Tilt Angle is set to - 2.5 degrees. As the beams are rotated around the altitude pivot point, the tilt angle changes the same number of degrees.

3. Weather targets and the Bright Band section. A typical storm showing its most reflective section as a black area along with the Bright Band. The altitude of the Bright Band is shown between 8,000 and 17,000 feet.



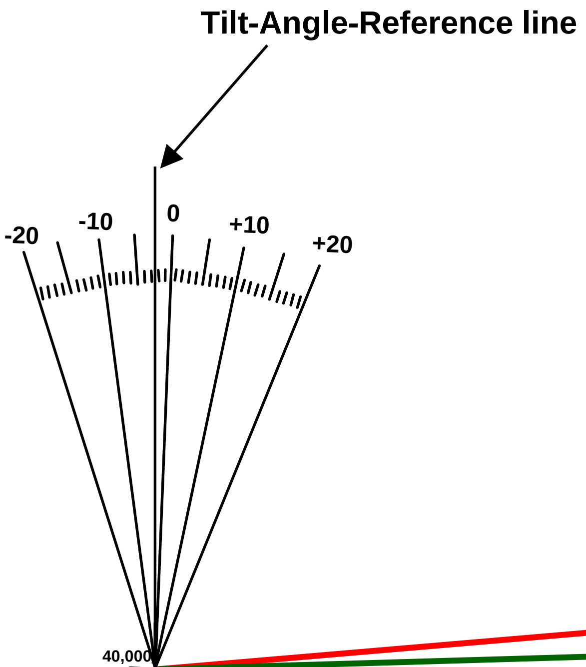
All the dimensions on the Radar Tilt-Angle Calculator are to scale.

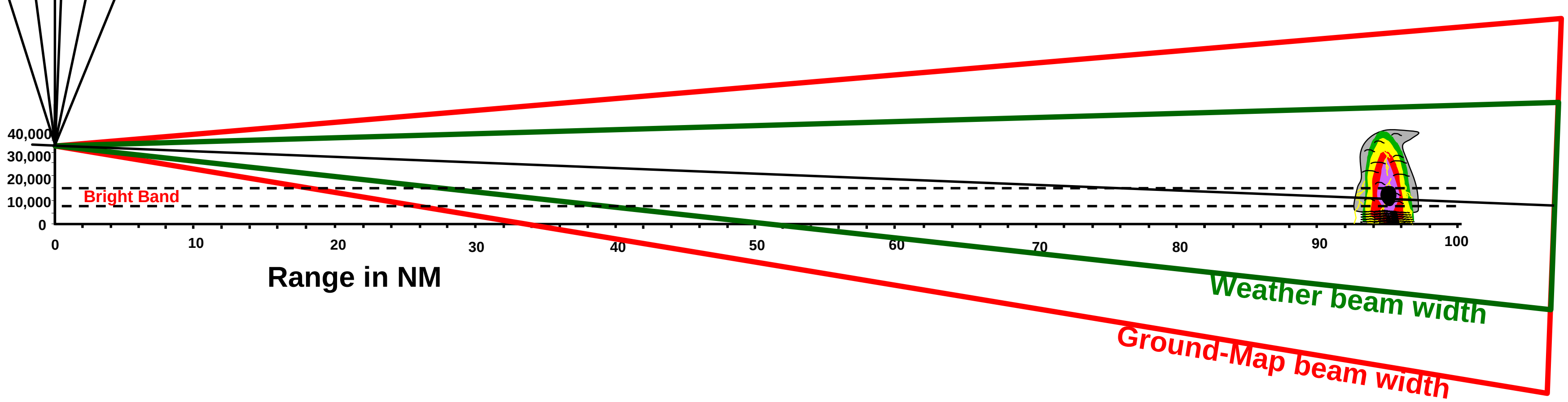
Radar Tilt-Angle Calculator

Here's how to use the Tilt-Angle Calculator:

1. **Set the aircraft's altitude on the vertical slider on the left (35,000 feet).**
2. **Position the Weather beam to be directed into the area of interest (the most reflective part of a storm).**
3. **Read the antenna tilt angle from the Tilt-Angle scale on the left (-2.5 degrees in this case).**

Using this tool, you can gain an appreciation of how the radar's beam and a weather system interact!





In order to understand the following Tilt-Management example, it is very helpful to understand this concept

→ 5 audio segments

The total reflection from a thunderstorm is due to the summation of the energy returned from all the rainstorm's reflectors that are within its weather beam width. These reflectors can be in the form of raindrops, hail, ice crystals and snow.

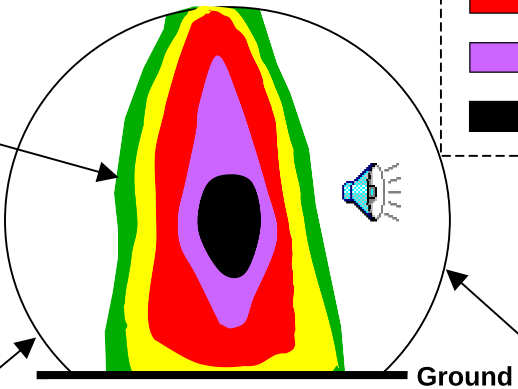
Color-contribution factor (relative strength of that color's reflection)

Green	1
Yellow	10
Red	100
Magenta	1,000
Black	10,000

Each Color's Contribution = (the color's area in percent) X (the area's color-contribution factor)
(within the weather beam width)

This is with respect to the total colored area.

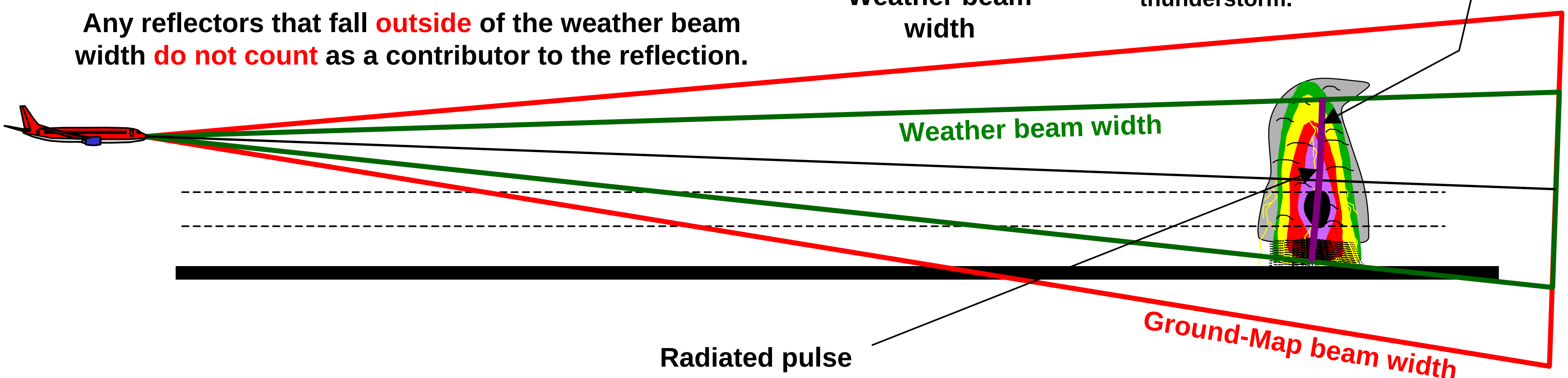
Total Reflection = Black's contribution + Magenta's contribution
+ Red's contribution + Yellow's contribution
+ Green's contribution



Down-beam view of the thunderstorm.

Weather beam width

Any reflectors that fall outside of the weather beam width do not count as a contributor to the reflection.

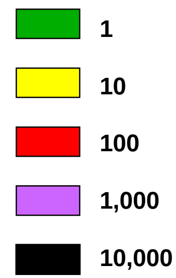


Radiated pulse from the radar.

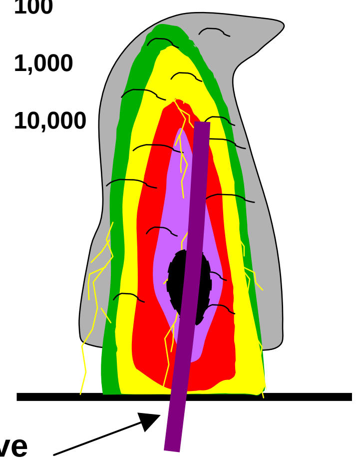
			Reflectivity-Contribution Calculation				
Display Color	A Percent of the illuminated storm		Percent converted to a decimal number format		Signal power reflection weight of the color		Signal power contribution from the color
Green	15.4%		0.154	X	1	=	0.154
Yellow	23.3%		0.233	X	10	=	2.33
Red	36.3%		0.363	X	100	=	36.3
Magenta	17.5%		0.175	X	1000	=	175.0
Black	7.5%		0.075	X	10000	=	750.0
	This is the reference start point of 100%.		B		Total from all colors C	=>	963.8 D

Finding the Optimum-Tilt Angle

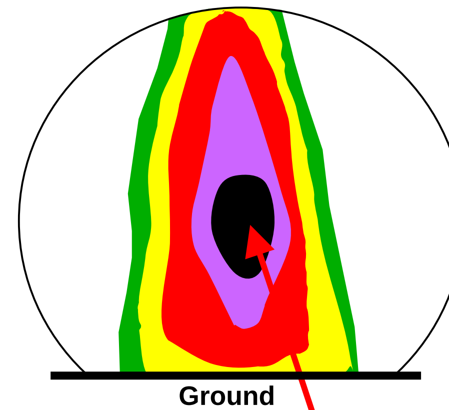
Color-contribution factor



Expanded view of the storm



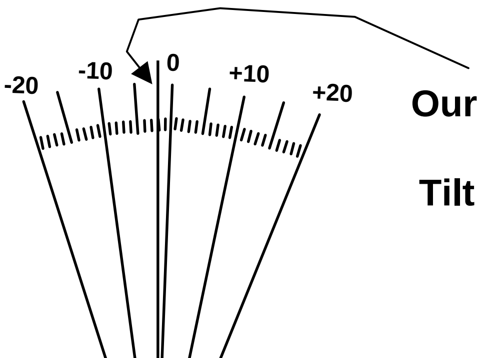
Total = 964
(the reference)

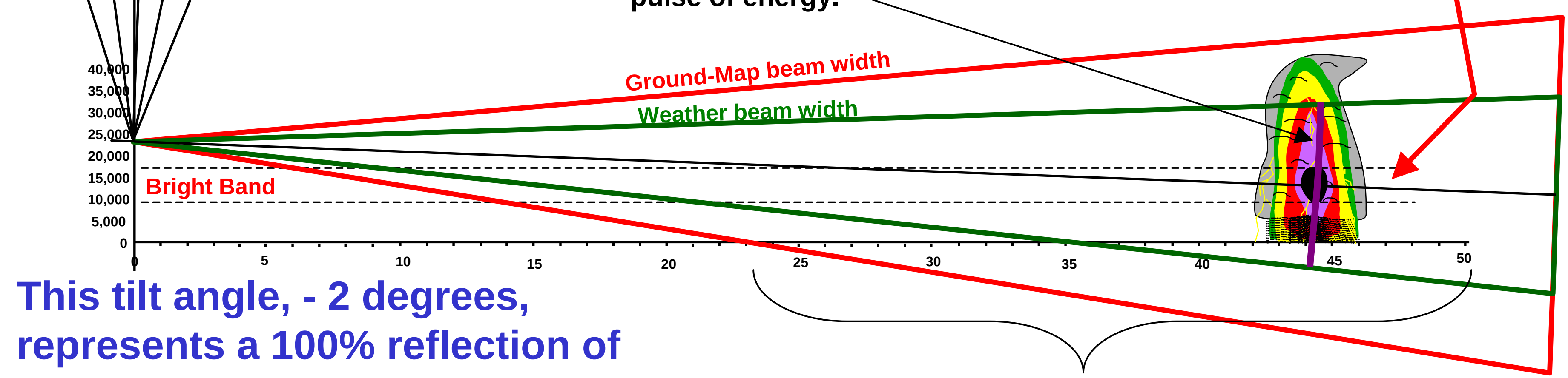


Our absolute maximum start point is:
Tilt Angle = -2 degrees

Radiated microwave pulse of energy.

The Bright Band (the space between the dashed lines)





This tilt angle, - 2 degrees, represents a 100% reflection of the weather.

54% Display Ground clutter (that's a lot)

Finding the Optimum-Tilt Angle

A more acceptable solution to some people would be to optimize the radar's presentation.

When we say optimize, we mean:

- **Maintain the storm's calibration (to within reason),**

and to

- **Remove as much ground clutter as possible.**

Let's see how well we can do:

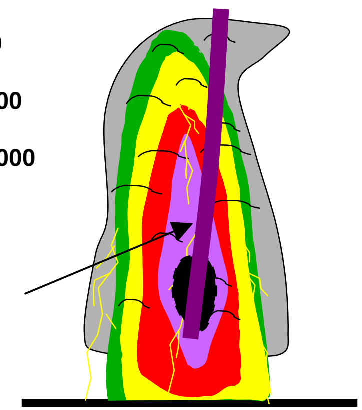
			Reflectivity-Contribution Calculation					
Display Color	Percent of the illuminated storm		Percent converted to a decimal number format		Signal power reflection weight of the color		Signal power contribution from the color
Green	13.5%		0.135	X	1	=	0.135
Yellow	18.0%		0.18	X	10	=	1.80
Red	29.0%		0.29	X	100	=	29.0
Magenta	14.5%		0.145	X	1000	=	145.0
Black	7.5%		0.075	X	10000	=	750.0
	82.5%				Total from all colors	=>	925.9

Finding the Optimum-Tilt Angle

Color-contribution factor

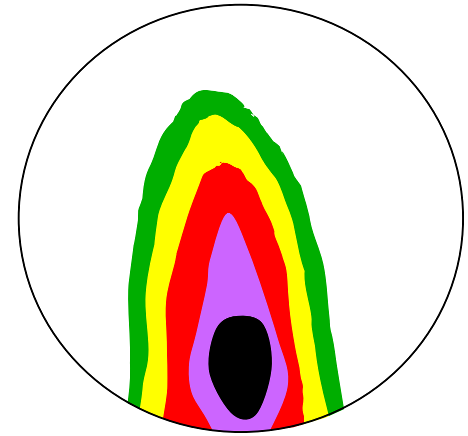
- Green: 1
- Yellow: 10
- Red: 100
- Magenta: 1,000
- Black: 10,000

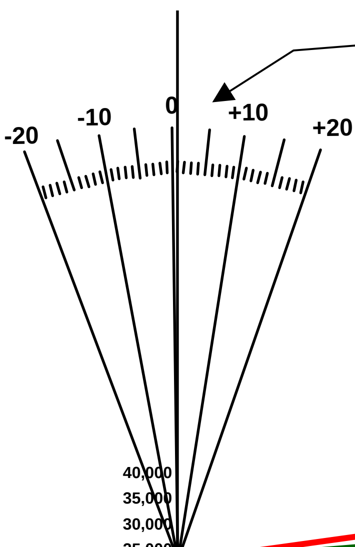
Expanded view of the storm



Radiated microwave pulse of energy.

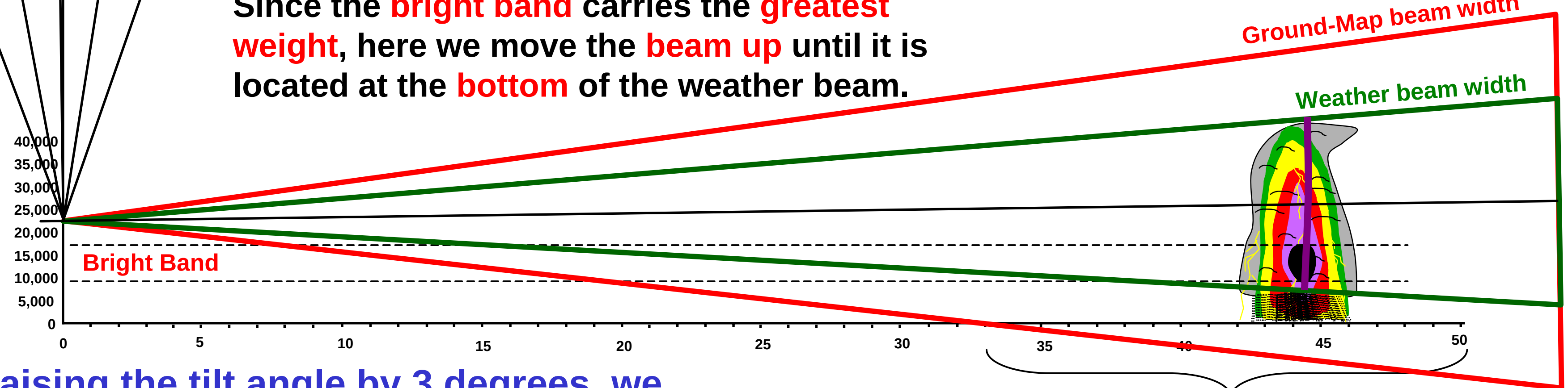
The new total = 926





Tilt angle has now been raised to +1 degree (up 3 degrees).

Since the bright band carries the greatest weight, here we move the beam up until it is located at the bottom of the weather beam.



By raising the tilt angle by 3 degrees, we only experienced a 4% signal reduction!

34% Ground Clutter (better)

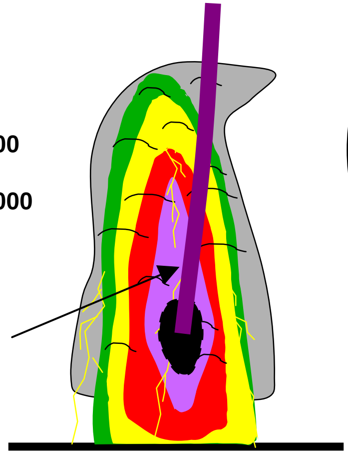
Display Color	Percent of the illuminated storm		Percent converted to a decimal number format		Signal power reflection weight of the color		Signal power contribution from the color
			Reflectivity-Contribution Calculation				
Green	8.0%		0.08	X	1	=	0.08
Yellow	9.0%		0.09	X	10	=	0.9
Red	14.4%		0.144	X	100	=	14.4
Magenta	9.6%		0.096	X	1000	=	96.0
Black	3.7%		0.37	X	10000	=	370.0
	44.7%				Total from all colors	=>	481.4

Finding the Optimum-Tilt Angle

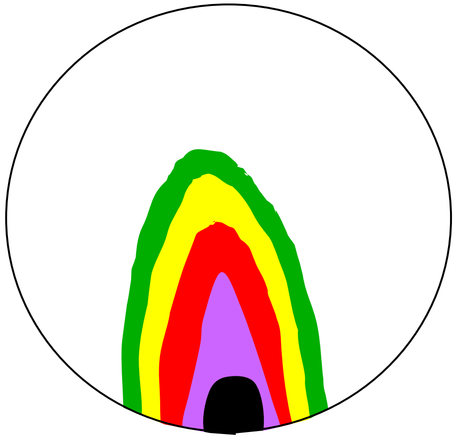
Color-contribution factor

Green	1
Yellow	10
Red	100
Magenta	1,000
Black	10,000

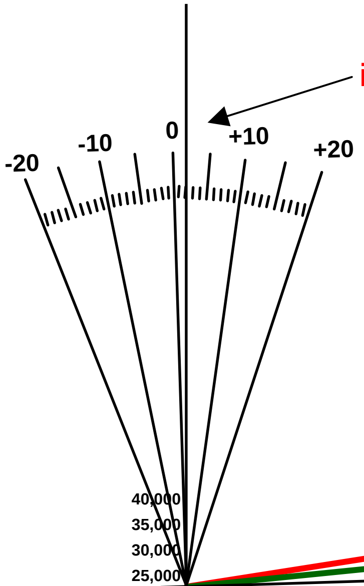
Expanded view of the storm



New total = 481

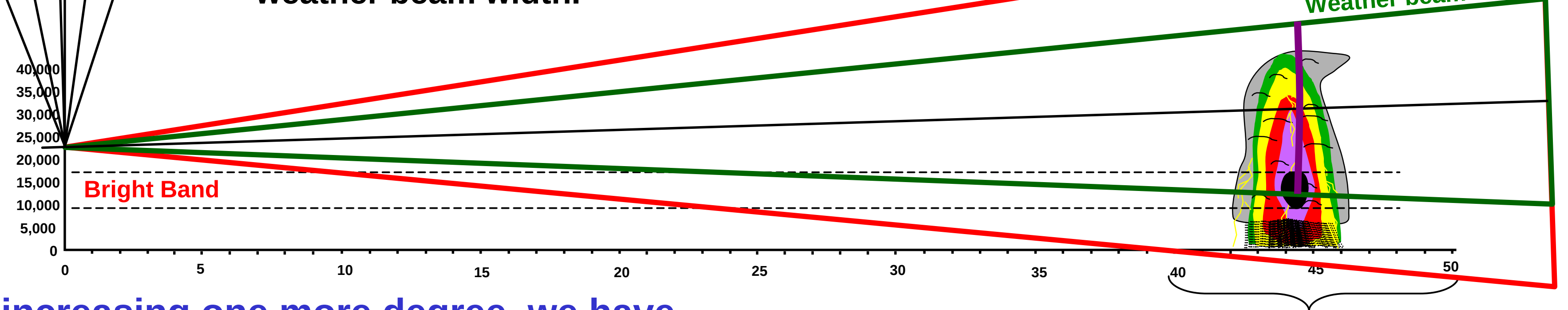


Radiated microwave pulse of energy.



Tilt angle has been increased to +2 degree (up another degree).

Here we push this concept a little bit further and move the tilt up until the bright band is cut in half by the bottom of the weather beam width.



24% Ground clutter (better yet)

By increasing one more degree, we have experienced a 50% signal reduction!

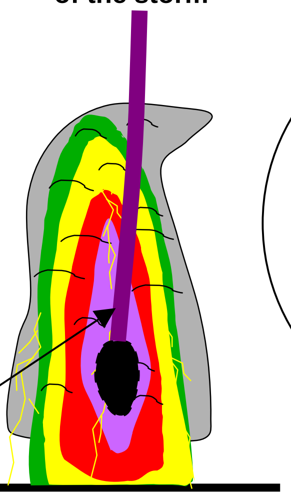
Finding the Optimum-Tilt Angle - Section 3

Display Color	Percent of the illuminated storm	Percent converted to a decimal number format		Signal power reflection weight of the color		Signal power contribution from the color
		Reflectivity-Contribution Calculation				
Green	5.0%	0.05	X	1	=	0.05
Yellow	7.0%	0.07	X	10	=	0.7
Red	11.0%	0.11	X	100	=	11.0
Magenta	5.3%	0.053	X	1000	=	53.0
Black	0.0%	0	X	10000	=	0.0
	28.3%			Total from all colors	=>	64.8

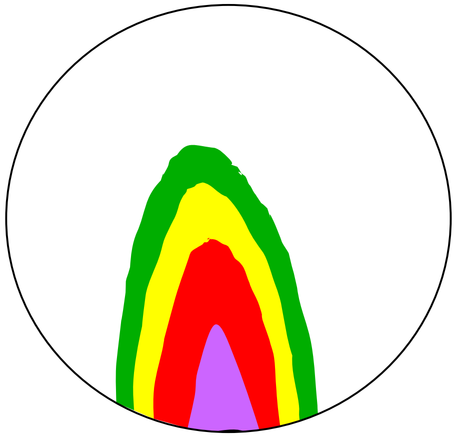
Color-contribution factor

Green	1
Yellow	10
Red	100
Magenta	1,000
Black	10,000

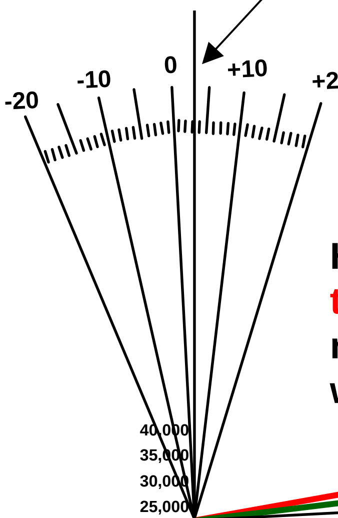
Expanded view of the storm



New total = 65

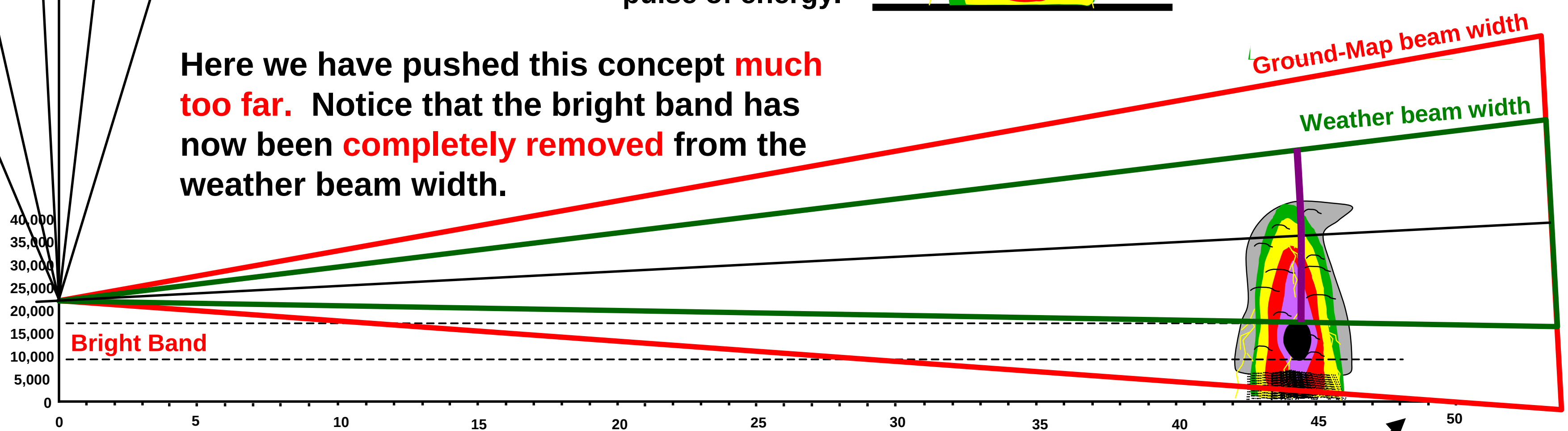


Tilt angle has been increased to +3 degree (up another degree).



Radiated microwave pulse of energy.

Here we have pushed this concept much too far. Notice that the bright band has now been completely removed from the weather beam width.



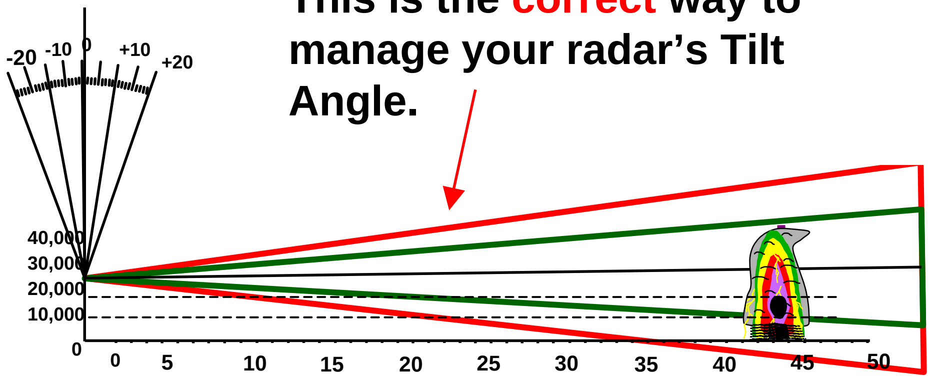
Another degree up tilt produces a 93% signal loss.

Now there is only 8% ground clutter. Even better but we have completely lost the weather's calibration.

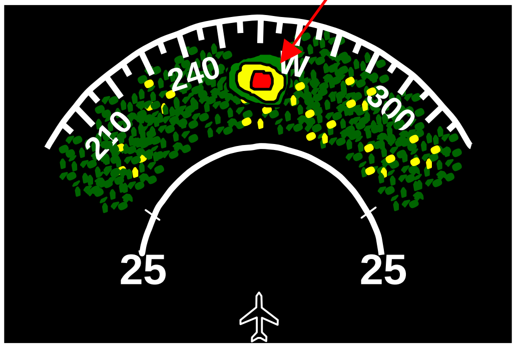
Tilt management technique comparison:

Finding the Optimum-Tilt Angle

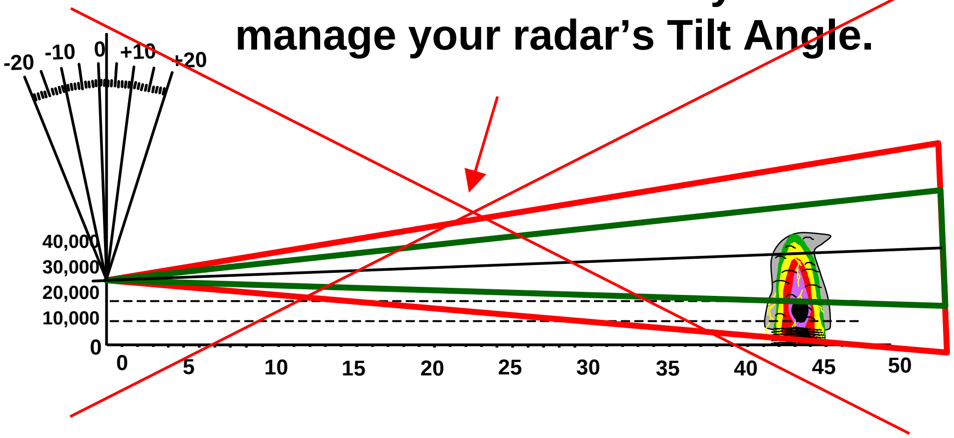
This is the correct way to manage your radar's Tilt Angle.



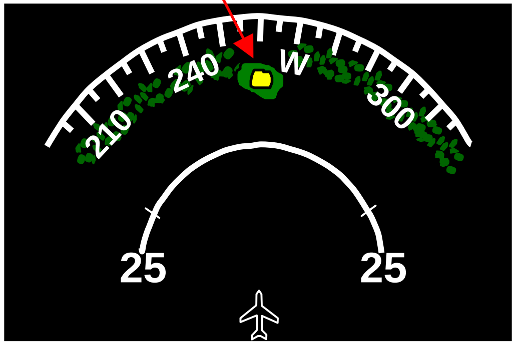
This is a Calibrated representation of the weather's danger.



This is the incorrect way to manage your radar's Tilt Angle.



This is a grossly understated representation of the weather's danger.

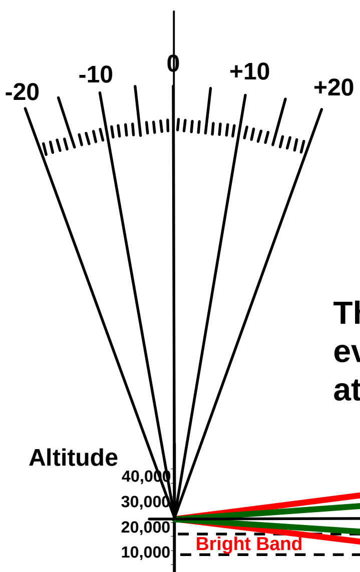


Finding the Optimum-Tilt Angle

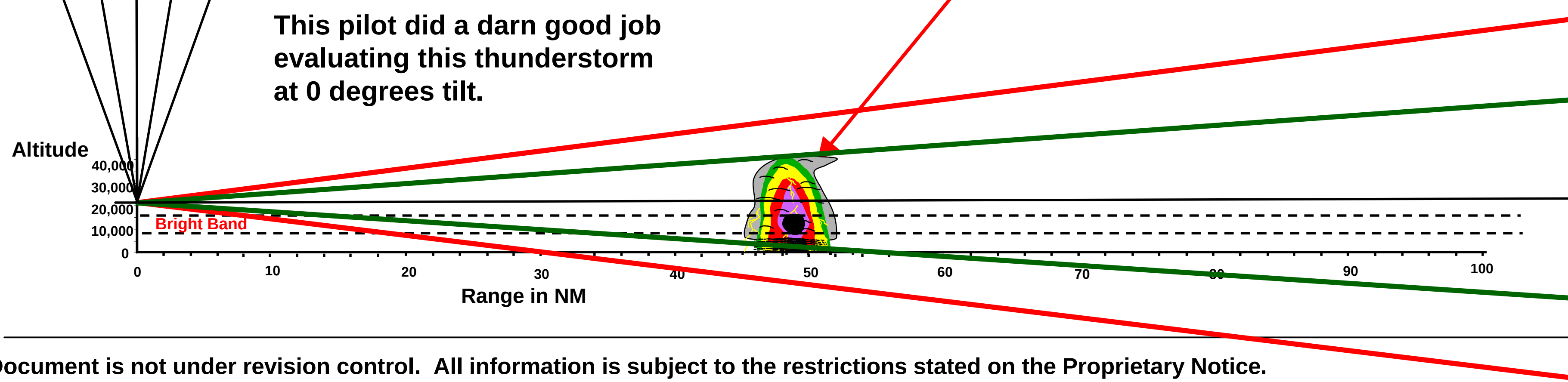
ERJ-145 aircraft

Key takeaway:

Point the weather beam width to just include the bottom of the thunderstorm's bright band (sometimes called the storm's core).



This pilot did a darn good job evaluating this thunderstorm at 0 degrees tilt.



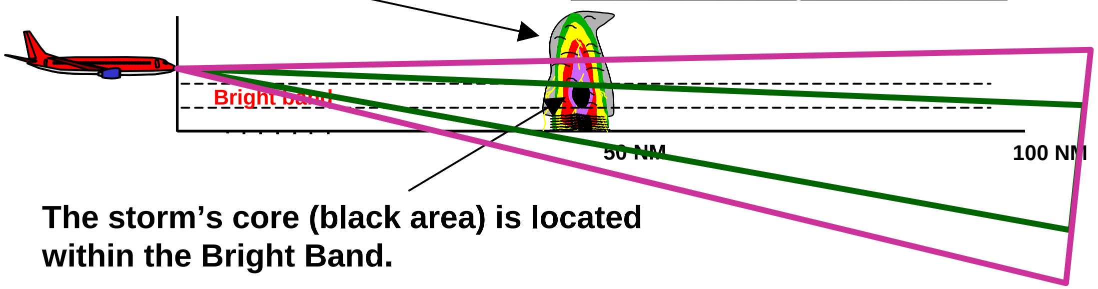
Tilt-Management Procedure Summary

Step 1. Search for weather targets by first looking for shadows with a considerable amount of ground clutter on the radar's display (no weather targets are shown in this picture).

Weather-detection beam

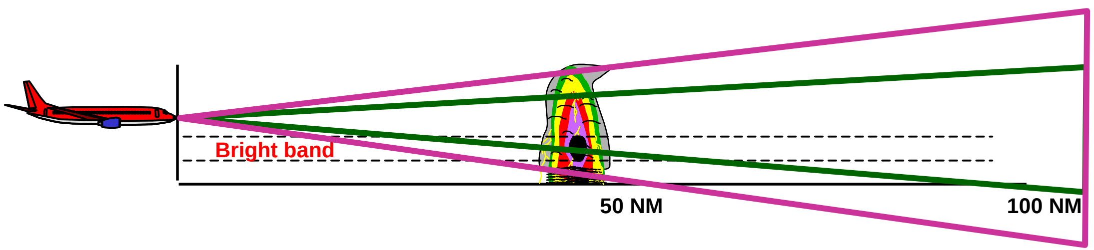
Ground-clutter-detection beam

Dangerous thunderstorm

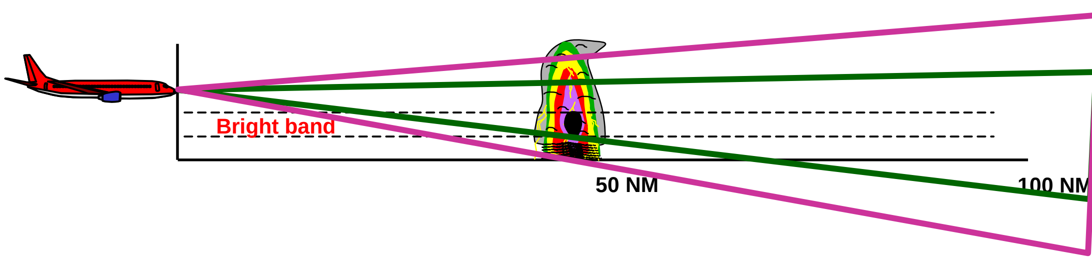


The storm's core (black area) is located within the Bright Band.

Step 2:
If you do observe a shadow (see picture below), adjust the tilt angle to maximize a weather target accepting significant ground clutter.



Step 3:
Adjust the tilt angle up until you start to lose the weather target's strength because you have moved the weather beam above the storm's core.



Step 4:
Down tilt to re-maximize the weather target while minimizing the ground clutter. That's it!

Radar shadow

Dangerous Thunderstorm

This Tilt-Management Procedure should normally take you about 20 seconds to complete.

Stratus Rain

Now let’s discuss the nemesis of Airborne-Weather Radar:

Stratus Rain.

Stratus Rain

Now that we know how to find dangerous thunderstorms, it’s time to address the rain scenario that causes a good deal of confusion, frustration and distrust by radar operators:

That’s finding Stratus Rain from high altitude.

A

B

Is this radar possibly faulty?

The answer is:

No the radar is not faulty.

That particular weather scenario is one the radar cannot easily resolve.

When viewing light rain from high altitude, as we now know, there are no significant radar shadows to help us find it, and the ground reflections are inextricably mixed up with the weather returns.

Stratus Rain

Once the aircraft descends to a low enough altitude to point the antenna in a direction which eliminates the ground clutter (that is, the radar's beam looks up at the weather), the radar can be used to circumnavigate the heavier-rain areas within the low-level, extended rain.

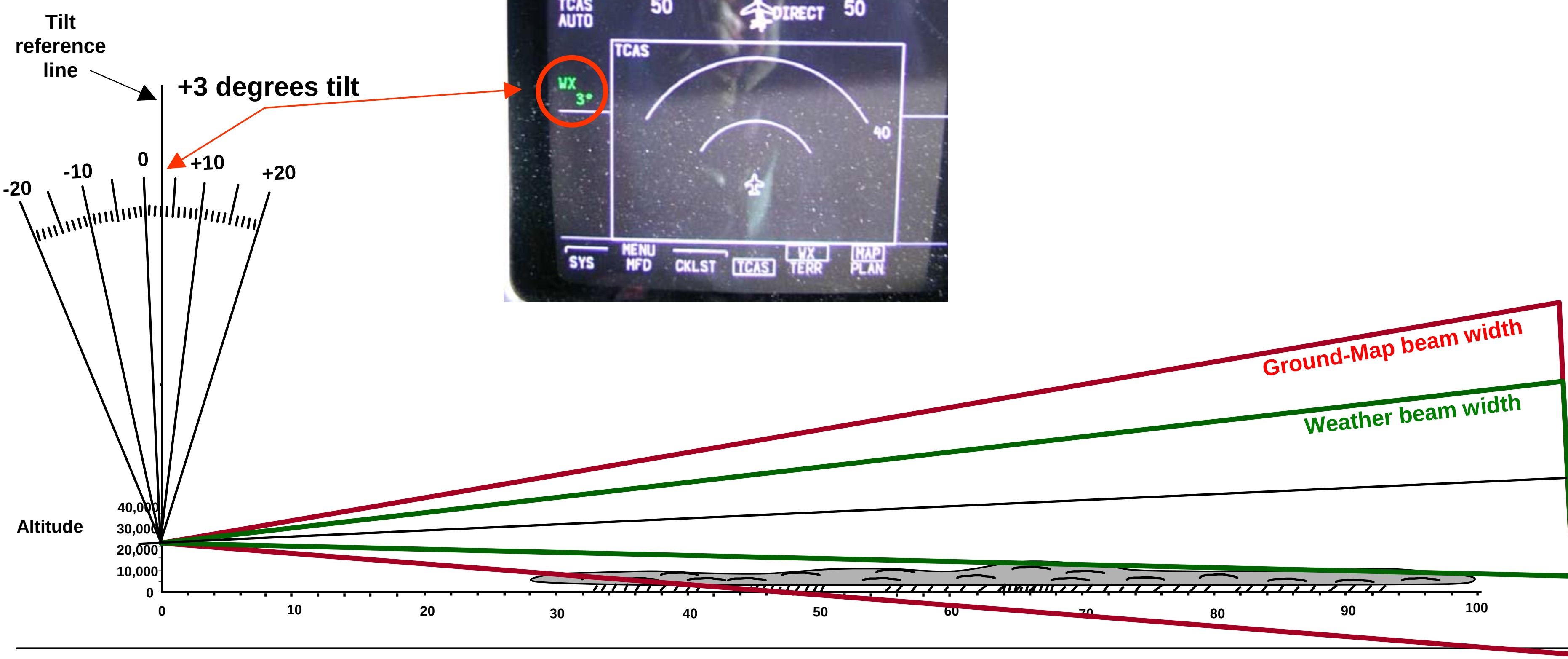
Unfortunately, if the radar operator does not fully understand this limitation, he or she may lose confidence in the radar's capability when this situation presents itself.

Stratus Rain

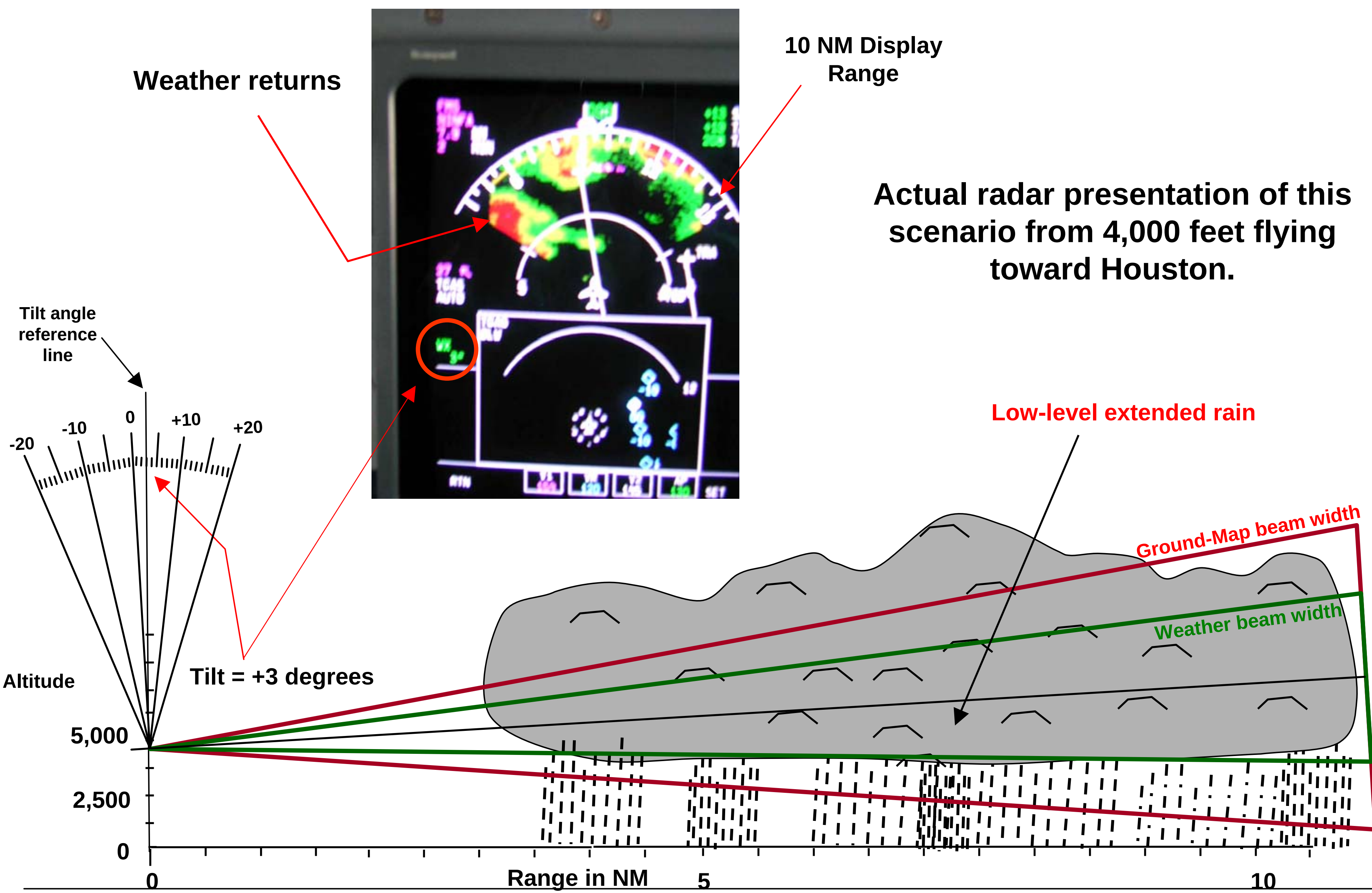
Weather and ground returns are all mixed together. The ground returns dominate the radar's presentation.

100 NM Display Range

This is an actual radar presentation resulting from this type of weather scenario. This picture was taken from 22,000 feet while flying toward Houston in an ERJ-145 aircraft.

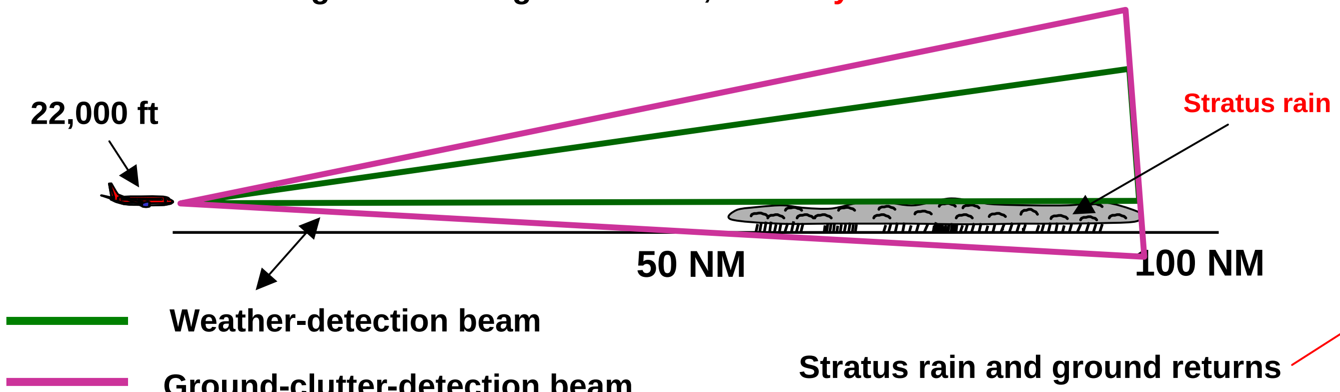


Stratus Rain



Stratus Rain Summary Page

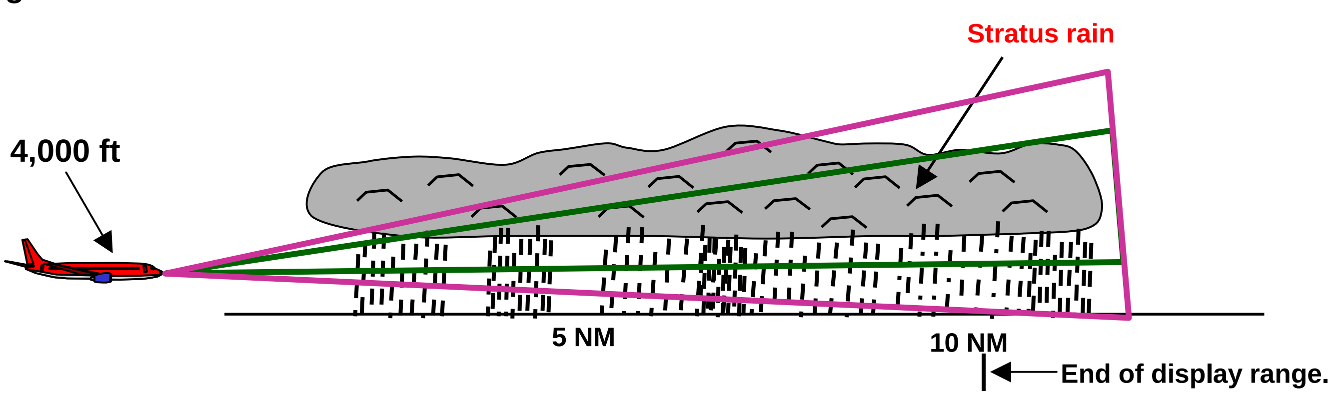
At high altitudes, in an attempt to observe Stratus rain, you must, by virtue of the geometry, also illuminate the ground with the radar's pulse energy. That's because Stratus rain only occupies low-altitude areas (usually less than 12,000 feet). The result is the Stratus returns will unsuccessfully compete against the strong ground returns. In that high-altitude flight scenario, it is very difficult to find the Stratus rain.



Stratus rain and ground returns are all mixed together.

All targets shown here are Stratus Rain.

At lower flight altitudes you can easily remove the ground returns simply by adjusting the Tilt Angle as shown below. The Stratus rain will be displayed prominently once the geometry is such that it no longer has to compete with the ground returns.



No audio

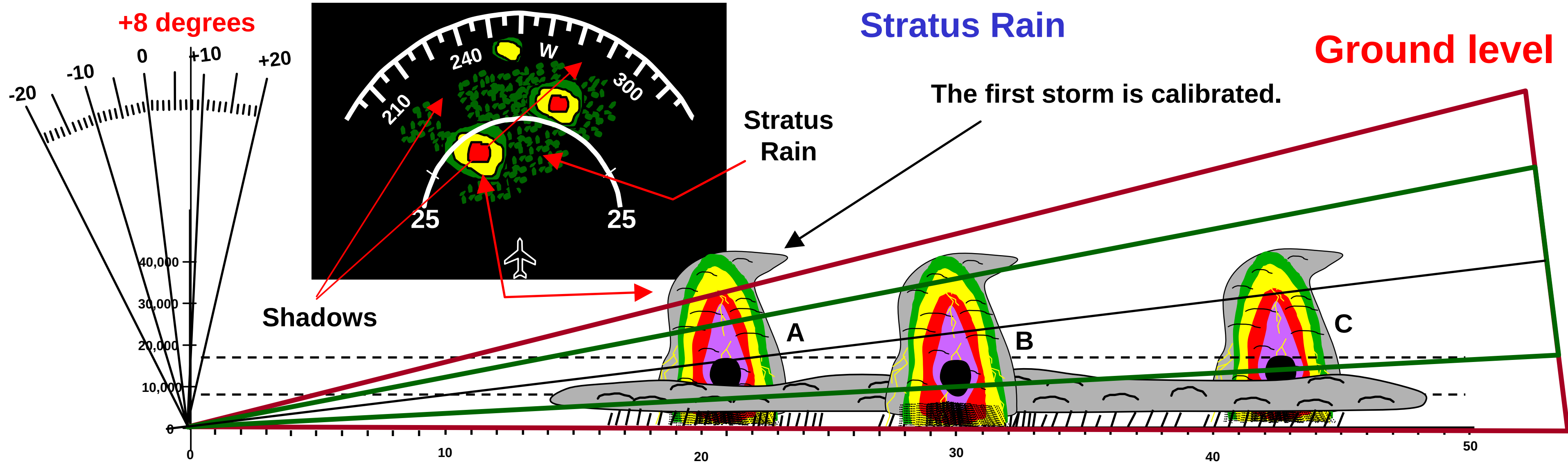
Stratus Rain - Section 3

Here is a practical question that many pilots seem to ask:

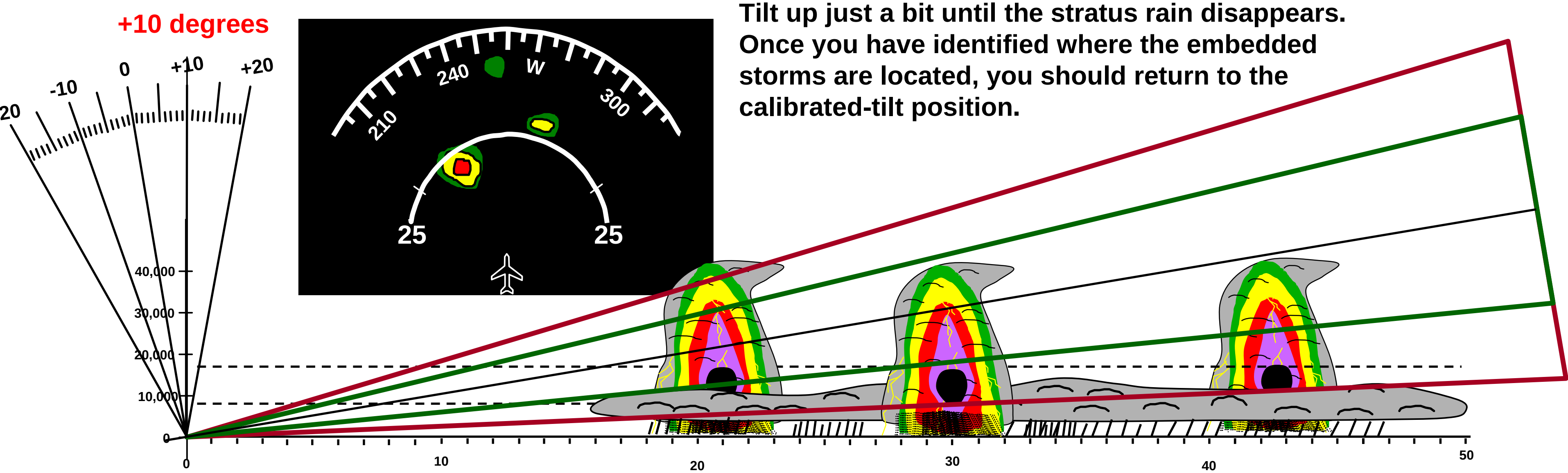
If you are faced with miles of stratus rain, how can you locate embedded thunderstorms?

Let's take some examples. We will look at ground level, low-altitude, middle-altitude and high-altitude scenarios:

Stratus Rain



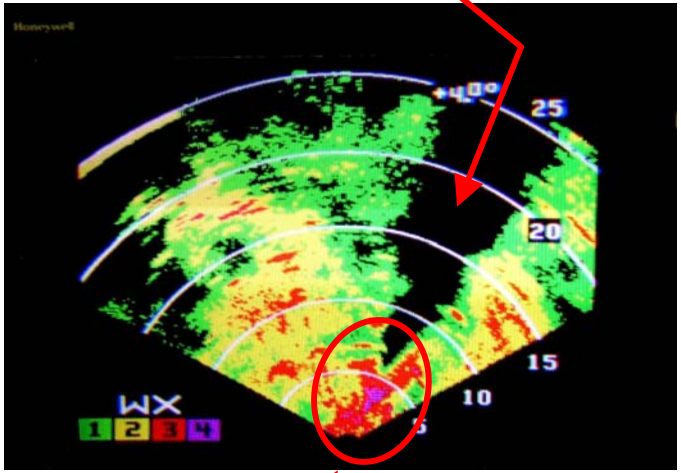
Tilt up just a bit until the stratus rain disappears. Once you have identified where the embedded storms are located, you should return to the calibrated-tilt position.



Stratus Rain

Actual Ground-Level pictures of Thunderstorms that are casting radar shadows into surrounding Stratus Rain.

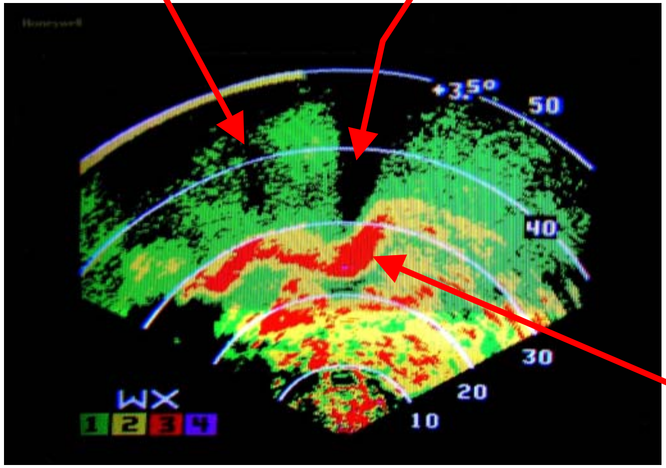
Here is a very well defined radar shadow cut into the Stratus rain area.



A Thunderstorm with a level-4 core.

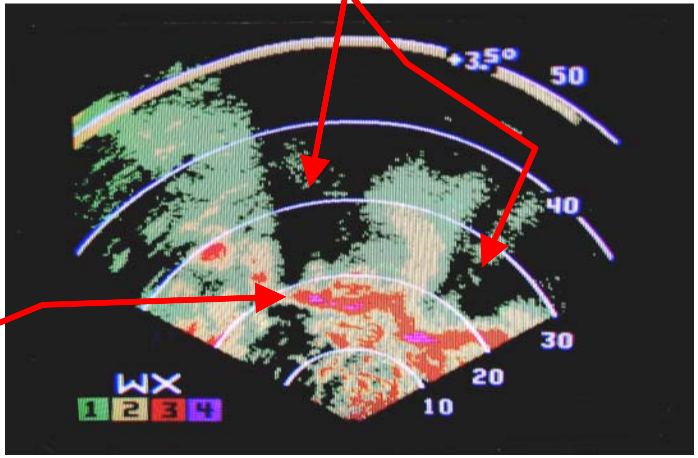
A fairly small radar shadow.

A nice radar shadow demonstrating the attenuation of the Stratus rain's returns.



Thunderstorm

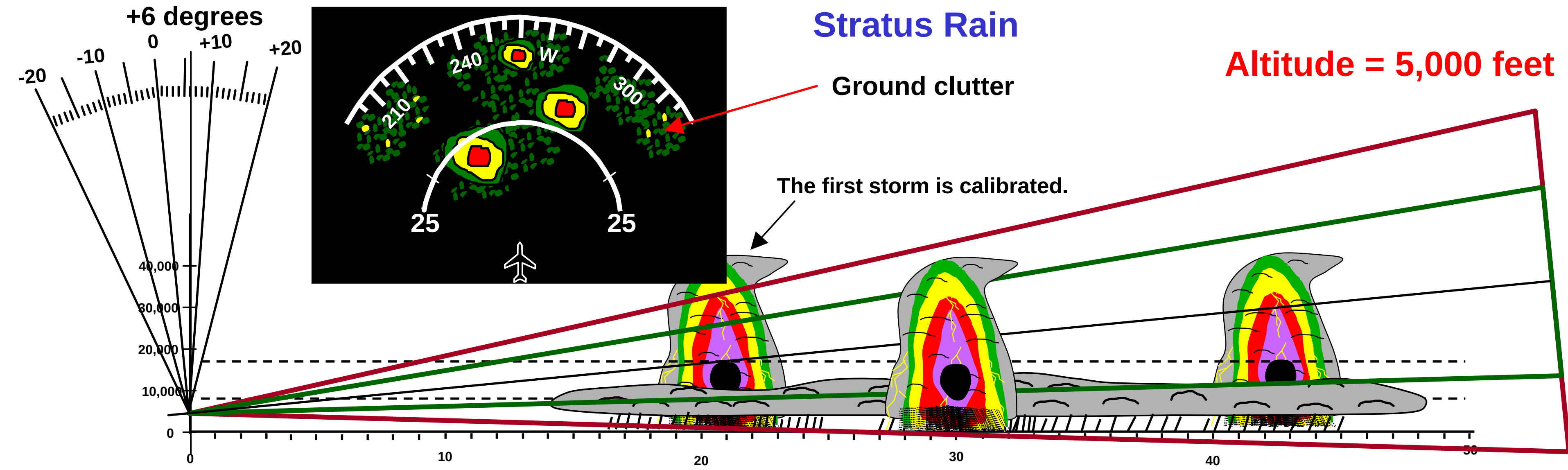
This storm is casting two rather significant radar shadows into the Stratus rain areas.

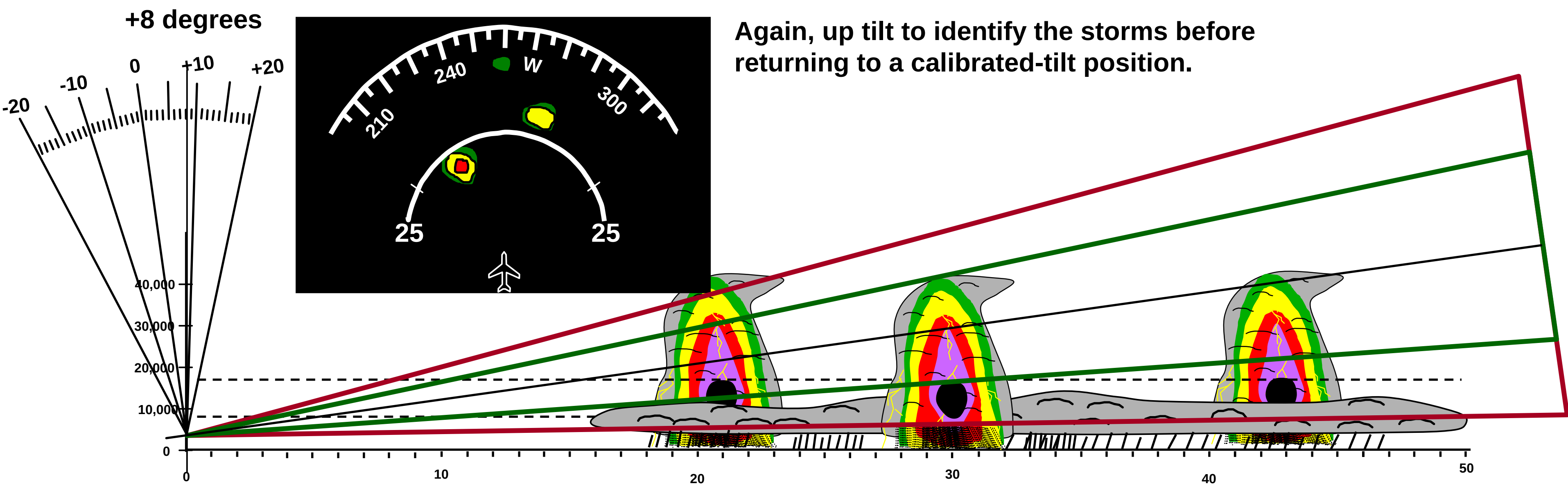


A long and twisted thunderstorm.

Stratus Rain

Altitude = 5,000 feet





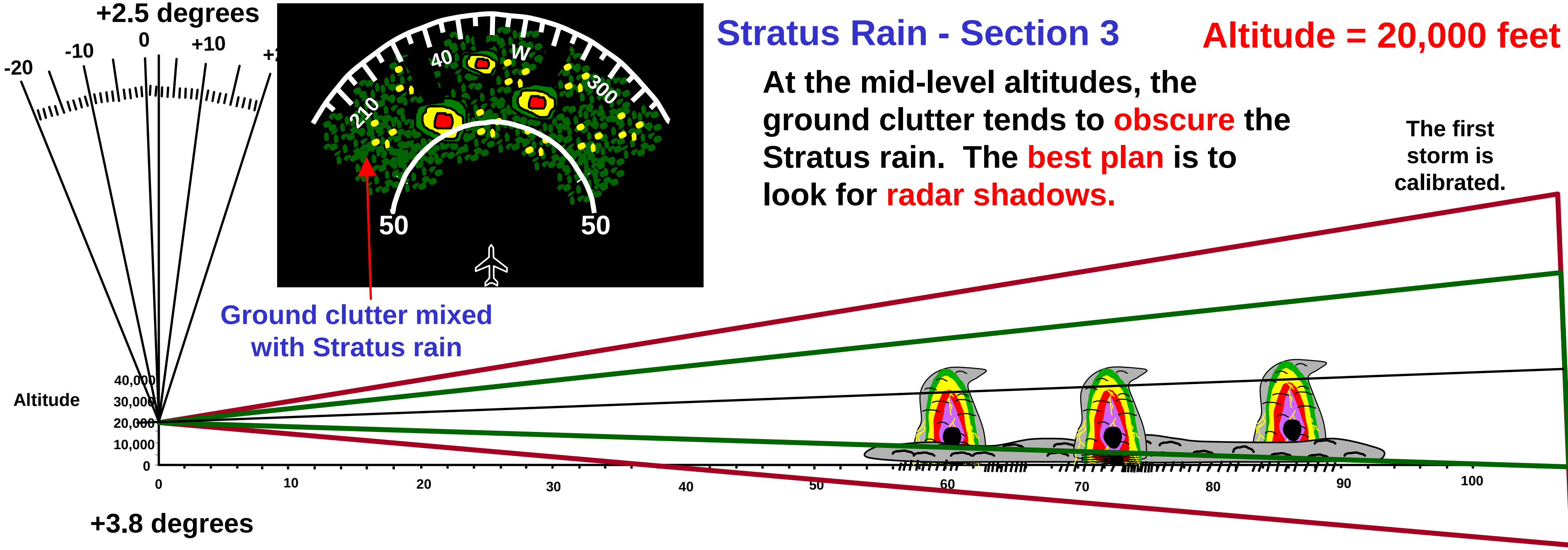
Again, up tilt to identify the storms before returning to a calibrated-tilt position.

Stratus Rain - Section 3

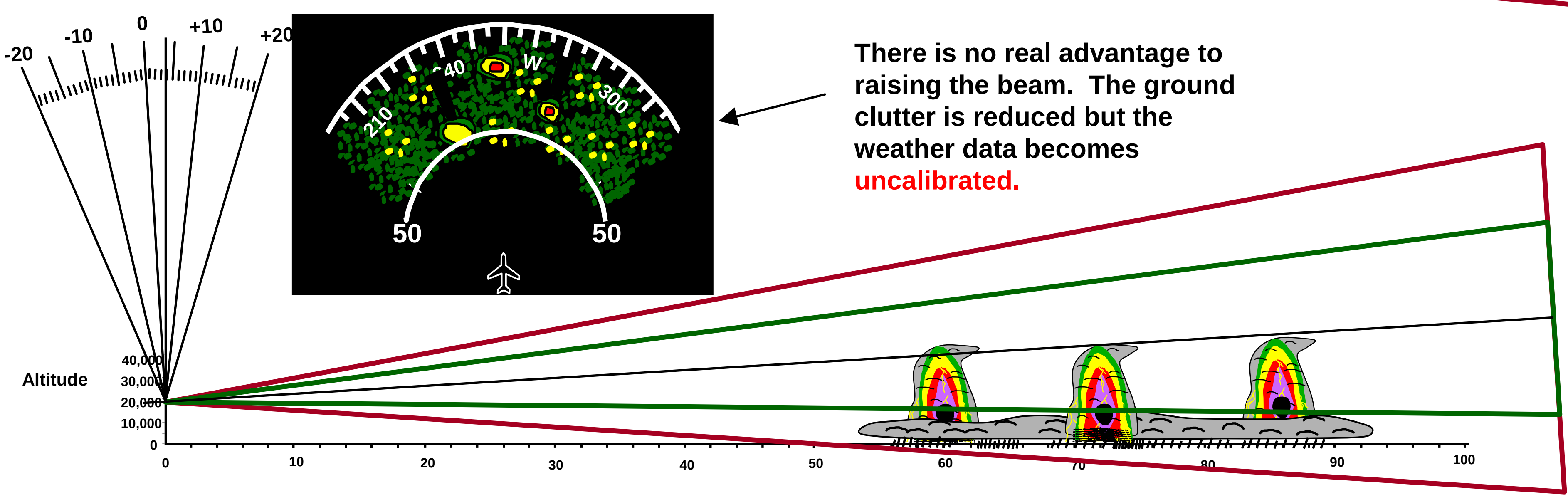
Altitude = 20,000 feet

At the mid-level altitudes, the ground clutter tends to obscure the Stratus rain. The best plan is to look for radar shadows.

The first storm is calibrated.



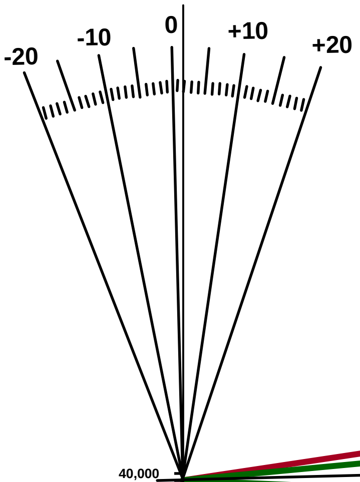
There is no real advantage to raising the beam. The ground clutter is reduced but the weather data becomes uncalibrated.

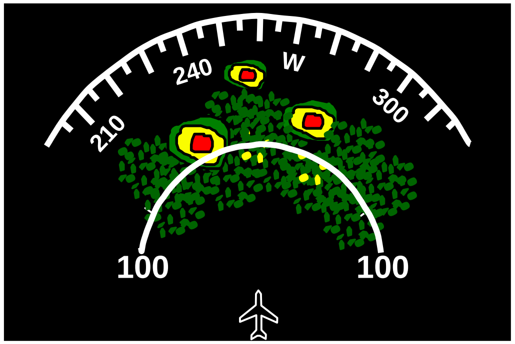


Stratus Rain

Altitude = 35,000 feet

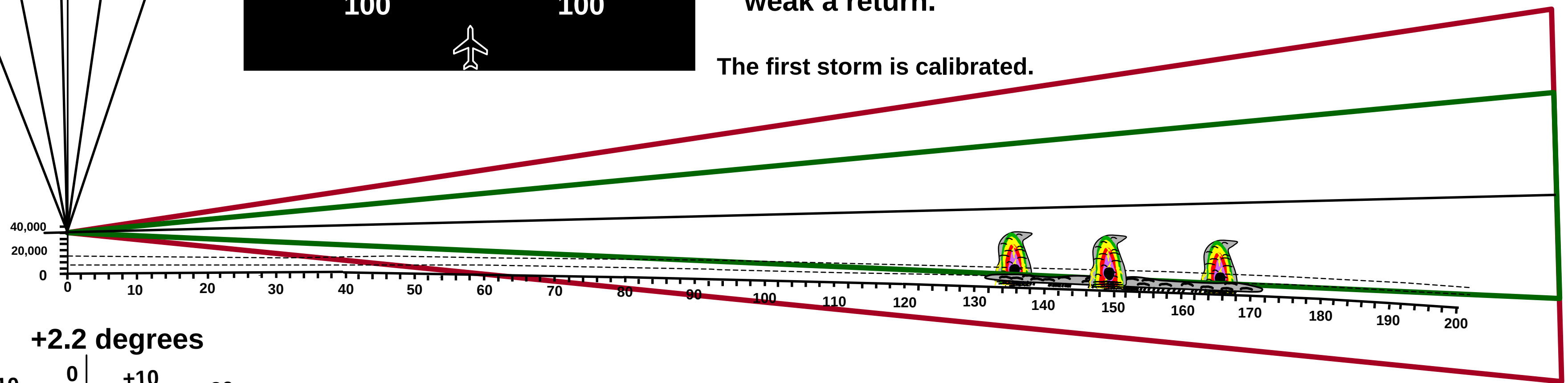
+1.9 degrees



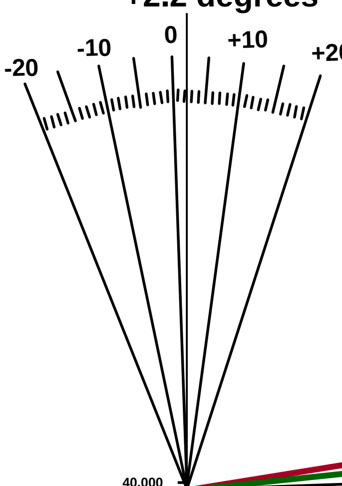


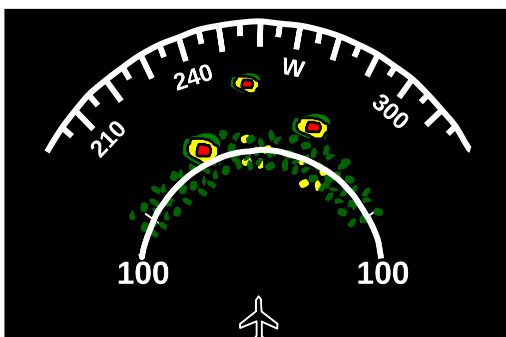
At the higher altitudes, with the weather targets calibrated, the ground clutter fades at about 120 NM due to the very low grazing angle. The stratus at that distance cannot be detected because it provides too weak a return.

The first storm is calibrated.

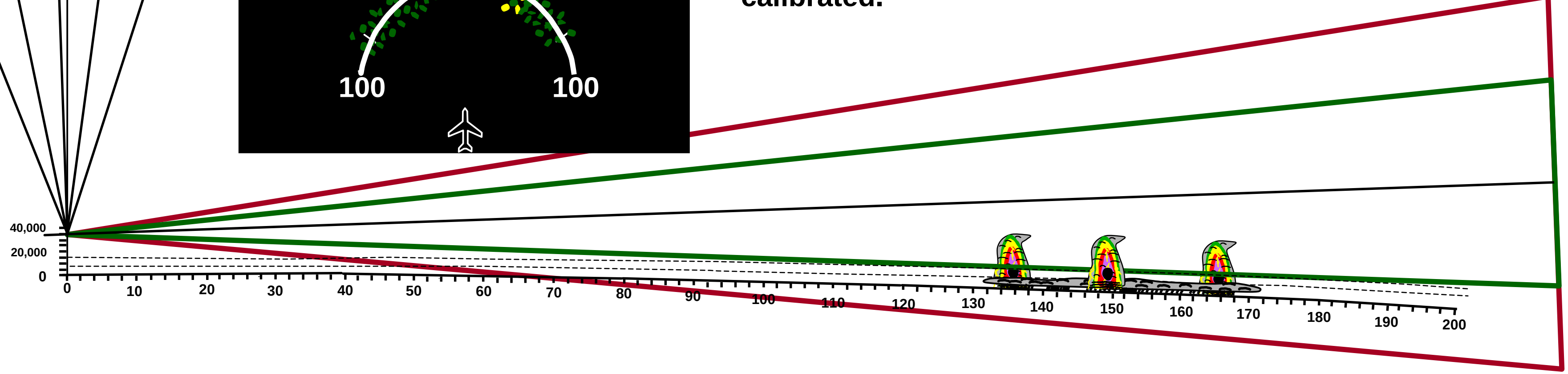


+2.2 degrees





By lifting the beam, you will reduce the ground clutter but you will also lose storm signal power. It's best to keep the storms calibrated.



No audio

A typical flight

General safety rules

Don't accept a vector from ATC into convective weather. Always ask for an alternate route. When you do refuse a vector, always try to give them adequate warning time so they can plan for aircraft-spacing adjustments. That is, try to avoid last-minute decisions.

Don't plan a course between two closely spaced thunderstorms (storms with less than 40 NM between them).

Don't land or takeoff in the face of a thunderstorm that is in the projected flight path. A sudden wind shift or low-level turbulence could cause loss of control.

Don't attempt to fly under a thunderstorm even if you can see through to the other side. Turbulence under the storm could be severe.

Don't fly over thunderstorms. Turbulence above a storm can be severe.

Do avoid by at least 20 NM any thunderstorm identified as severe or giving an intense radar echo. This distance rule includes the anvil of a large cumulonimbus cloud.

Do clear the visual top of a known or suspected severe thunderstorm by at least 10,000 feet. If that exceeds the capability of the aircraft, go around the storm by a wide safety margin on the upwind side.

Do remember that vivid and frequent lightning indicates a severe thunderstorm.

Do regard as severe any thunderstorm with tops 35,000 feet or higher regardless of how you locate it--visual, radar or from a report.

Do evaluate weather scenarios from a distance and always plan an escape route at the top of a descent.