

FAMILY KIT - FOR THE CHILD

The planes that talk

A story in six chapters about a secret that is happening right above your house, right now. Read it with a grown-up, and try the things in the boxes as you go.

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CHAPTER 1

The sky is full, and nobody can see it

Go to a window and look up. Maybe you can see a plane, a tiny glint with a white line behind it. Maybe you can't see any at all. But here is the secret: there is almost always a plane above your town. Usually there are several. They are so high up, ten kilometres, that is ten thousand metres, higher than any mountain in Europe, that you can hardly see them, and the people inside the planes can hardly see each other either.

And they are fast. A big plane up there goes about 900 kilometres every hour. That is 250 metres every single second. If you blink, it has moved the length of two football pitches. Now imagine thousands of them, all over Europe, all going in different directions, all at once, and none of them able to see the others properly. Somebody has to make sure they never get too close. That somebody is called an air traffic controller, and the rule is that planes must always stay at least three hundred metres apart, up and down, that is three football pitches standing on end, or several kilometres apart side to side.

But how can a controller sitting in a room on the ground know where every plane is, every second, when the planes are ten kilometres up and hidden by clouds? That is the question this whole story is about. The answer is clever, and it is a bit magical, except that it is not magic at all. It is science, and by the end you will understand every bit of it.

Try it: the five-minute count

Look out of the window for five minutes and count every plane you see or hear. Write the number down. Then ask your grown-up to open the plane map on their phone and zoom in on your town. Count the planes on the map. Was it more than you counted? It almost always is. Every one of those planes on the map is doing the thing in chapter 2.

CHAPTER 2

Thunder, lightning, and how a plane knows where it is

Have you ever counted the seconds between a flash of lightning and the rumble of thunder? If you count to three, the storm is about one kilometre away. If you count to nine, it is three kilometres away. It works because the flash of light reaches you straight away, but the sound of the thunder is slow, and the further away the storm is, the longer the sound takes to get to you. So the **delay tells you the distance**.

Remember that, because it is the trick that planes use.

High above the planes, much higher, twenty thousand kilometres up in space, there are about thirty special satellites going round the Earth. Each one has a clock inside it that is so exact it would not lose a second in a million years. And each satellite calls out, all the time, by radio: "I am satellite number twelve, I am exactly here, and the time is exactly now." It does not care who is listening. It just keeps saying it.

The plane listens. Radio is very, very fast, but twenty thousand kilometres is a long way even for radio, so the satellite's call arrives at the plane a tiny bit late, about one fifteenth of a second. The plane's computer compares the time the satellite said with the time the call arrived. The delay tells the distance, just like thunder! So now the plane knows how far it is from satellite twelve. It does the same for three more satellites. And there is only one place in the whole world that is exactly the right distance from all four satellites at once. That place is where the plane is. The plane now knows where it is, to within a few metres, and it has worked it out all by itself.

Notice something: the satellites did not see the plane. They have no idea the plane is there. They just shout out the time, like a church bell striking the hour, and the plane does all the working out. Lots of people think satellites watch the planes. They don't. The plane listens to the satellites.

Try it: the clap and the torch

Stand at one end of the garden or a long room. Your grown-up stands at the other end and claps. Put your hand up the instant you hear it. Now do the same with a torch flash instead of a clap. The clap arrives a tiny bit late when you are far apart; the flash arrives at once. Light and radio are so fast you cannot notice the delay at home. But the satellites are so far away that even light takes a measurable moment to come down.

CHAPTER 3

The message: what a plane says, twice every second

So the plane knows where it is. Now comes the clever part. Instead of the people on the ground trying to find the plane, the plane simply **tells** them. Inside every big plane there is a small radio, and about twice every second, without anybody pressing a button, it sends out a message. The message has four parts: **who I am** (every plane has its own code, a bit like a number plate, that it keeps for its whole life), **where I am** (the position from the satellites), **how high I am**, and **how fast I am going, and which way**.

The plane does not wait to be asked. It does not send the message to anybody in particular. It just shouts it out to the whole world, twice a second, from the moment it starts moving until it is parked again. Other planes hear it, and use it to stay away from each other. The air traffic controllers hear it. And, as you will

find out in chapter 5, anybody with the right kind of ear can hear it too.

How can a radio "say" where it is? It cannot send words. It can only do one thing: send a tiny pulse, or not send one. So the message is made of yes-or-no answers, one hundred and twelve of them in a row, and everybody has agreed in advance what each one means. The first twenty-four yes-or-no answers spell the plane's name. Twenty-four yes-or-no answers might not sound like much, but there are nearly seventeen million different ways to answer them, which is enough for every plane ever built to have its own. The whole message of 112 answers takes about one ten-thousandth of a second to send. At the end are twenty-four extra answers that work like a check, so that if the message got muddled on the way, perhaps because two planes shouted at the same moment, the listener can tell, and throws it away. It doesn't matter: the plane says it again half a second later.

Try it: be a plane

Hold your arms out and fly around the room. Every few steps, say your message out loud: "I am plane Zoom! I am next to the sofa! I am up high! I am going fast!" Your grown-up is the control tower, with a piece of paper, drawing where you are every time you speak. Then swap. Then try saying the message only once a minute and see how useless the tower's drawing gets. Now you know why real planes say it twice a second.

CHAPTER 4

A colour your eyes cannot see

The message leaves the plane as a **radio wave**. And here is something that surprises most grown-ups: a radio wave is light. Not *like* light. It *is* light. It is the same stuff that comes out of a torch or the sun, and it goes just as fast: three hundred thousand kilometres in one second, which is seven times round the whole Earth. Every second.

So why can't you see it? Think of a rope. If you shake one end slowly, you get big, lazy waves. If you shake it fast, you get lots of small, busy waves. Light is like that too. Red light wiggles very fast; blue light wiggles even faster. Our eyes are built to notice only a small band of wiggle-speeds, the colours of the rainbow. Radio wiggles far too slowly for our eyes to notice, even though it still wiggles more than a thousand million times a second. So radio is a colour, a very slow colour, that our eyes simply cannot see. Dogs can hear whistles you cannot hear. Bees can see patterns on flowers you cannot see. And antennas can see a colour of light you cannot see.

Because it wiggles slowly, the plane's wave is quite long: from one ripple to the next it is 27 centimetres, about as long as a school ruler. Thousands of those ripples are passing through your room right now, from every plane within four hundred kilometres, and you cannot feel a single one.

One more very important thing. Radio is **not sound**. A box called "a radio" makes sound, which is confusing, but the radio waves themselves are silent light. Sound is air pushing on air; it is slow (about 340 metres a second, which is why thunder comes after lightning), and it needs air to travel through. Radio needs nothing at all: it crosses empty space from the satellites to the plane, where there is no air to carry a sound. The roar of a plane's engines is sound and reaches you long after the plane has passed. The plane's message is light and reaches the antenna almost before the plane has finished sending it.

Try it: the rope and the ruler

Tie a skipping rope to a door handle and shake the other end. Slowly: big waves. Fast: small waves. Measure one wave with a ruler each time. Then lay the ruler on the floor: the plane's wave is about that long, from one ripple to the next. Now switch on a torch and ask where the light is. Everywhere, straight away. The plane's message travels exactly like that.

CHAPTER 5**Metal ears, and why the Earth being round matters**

If radio is a colour we cannot see, what can? The answer is a piece of metal called an **antenna**. When a radio wave passes over a piece of metal, it makes the electricity inside the metal wobble back and forth in time with the wave. That tiny wobble is the "hearing", and a little machine called a receiver can read the plane's pulses from it. So an antenna is a metal ear. And like a real ear, it has a size that suits it: it hears the plane's wave best when it is a quarter as long as the wave, which is about 7 centimetres. That is why the antenna for this is a small stub, not a big dish.

Now, how far away can a metal ear hear a plane? You would think it depends on how loud the plane is. It does, a bit. But something else matters more, and it is this: **the Earth is round**. Radio is light, and light goes in straight lines, and it cannot go through the ground. So a straight line from an antenna on a roof soon runs into the curve of the Earth, and any plane that is behind that curve is hidden, however loud it is. It is exactly like a ship sailing away: first the hull disappears below the horizon, and then the mast.

The higher you are, the further you can see over the curve. You know this already: standing on a chair, you can see over a crowd. That is why antennas are put on roofs, on masts and on hills. From a roof, an antenna can hear a plane that is ten kilometres high from more than four hundred kilometres away, which is further than Brussels to Paris and back. But a plane that has just taken off from an airport fifty kilometres away may be completely hidden behind the Earth, and the antenna will not hear it until it climbs high enough to peep over the curve.

Try it: the antenna hunt and the horizon walk

Find five antennas in and around your home. Clues: the Wi-Fi box, the car's roof, the house roof, a radio, and one hidden inside the phone. Notice how many are up high. Then go somewhere with a view. Crouch, then stand, then sit on your grown-up's shoulders. What appears each time you go higher? That is what a roof does for an antenna.

CHAPTER 6**Many ears make one map**

One antenna on one roof can hear the planes in a circle of sky a few hundred kilometres across. That is a lot, but it is not all of Europe. So there are hundreds of antennas, on houses and airports and schools, and each one sends what it hears, over the internet, to a computer. The computer fits all the pieces together, like a jigsaw where every piece is one antenna's circle of sky. The same plane is usually heard by ten or twenty antennas at once, and the computer notices it is the same plane and does not draw it twenty times.

The result is the live map. Every plane that is talking, where it is, how high, how fast, which way, updated every second. And now you know the whole secret of how it works, from start to finish: the plane listens to the satellites and works out where it is; it says so twice a second in a message of 112 yes-or-no answers; the message rides on a wave of invisible light; a metal ear on a roof catches it, as long as the plane is above the curve of the Earth; and hundreds of ears together make the map. Nobody on the ground ever measured anything. The planes told us, and we listened.

One last thing, because a good detective always asks it. Does the map show *every* plane? No. It shows the planes that are talking. Nearly all the big airliners talk. Some small planes, gliders and balloons do not have the radio, and some military planes choose to stay quiet. So the map is honest, but it is not complete. No map ever is.

Try it: find your plane

Open the plane map with your grown-up and zoom in on your house. Wait for a plane to pass overhead, find it on the map, and tap it. Read its name, its height and where it is going. Then look up at the real plane and think: that one is saying its message right now, twice a second, and somebody's metal ear caught it, and that is why I can see it on the map. Then ask yourself: what would happen if it stopped talking?

Did you get it? Three questions

Think of your answer first, then press the button to check.

1. Do the satellites watch the planes?

2. Is a radio wave a kind of sound?

3. Why is the antenna on the roof?

THE END OF THE STORY

Could you have metal ears of your own?

Yes. A real listener for planes fits in a shoebox: a small antenna, a stick that plugs into a tiny computer, and the internet. A grown-up can build one with you in an afternoon, and when it works, the planes that fly over your house appear on the big map because your ears heard them. Ask a grown-up to open the workshop page with you.

Show a grown-up the workshop <https://radar.dataero.eu/learning/workshop>

Answers

1. Do the satellites watch the planes?

No. The satellites just call out the time, like a church bell. The plane listens, works out how far away each satellite is from the delay, and finds its own position. Then it tells everyone.

2. Is a radio wave a kind of sound?

No. It is a kind of light, a colour our eyes cannot see. It needs no air, it crosses empty space, and it travels nearly a million times faster than sound.

3. Why is the antenna on the roof?

Because the Earth is round and radio goes in straight lines. The higher the antenna, the further its straight line reaches over the curve before it hits the ground, so the further away it can hear planes.