

AGES 6 TO 11 - FOR THE TEACHER

The planes that talk: a primary science course in four lessons

This is the course as the teacher needs to know it: the science explained one level deeper than the class will hear it, the order in which the ideas have to come, what to say at six and what to add at ten, the demonstrations that carry each idea and why they work, and the wrong ideas children bring with them. Four lessons of about 50 minutes, usually spread over two weeks.

Learn - <https://radar.dataero.eu/learning/ages-6-11> 2026-10-22

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Before you start: what the course teaches and why it is worth four lessons

Every airliner in European skies broadcasts, about twice a second, a short radio message giving its identity, its position, its altitude and its speed. The system is called ADS-B, and since 2020 it has been compulsory for most aircraft. Air traffic controllers rely on it; so do the live flight maps on any phone. For a primary class it is an almost perfect subject, because it joins things children already wonder about, the planes they see and hear, to the physics the curriculum asks you to teach: that light and sound are different kinds of thing, that light travels in straight lines, that waves have a length, that the Earth is a sphere and this has visible consequences, that information can be coded and sent, and that a map is made from measurements. The subject is real and current; nothing in it is a toy model.

The course follows the logic of the system itself, because that logic is also the right teaching order. First the class must grasp that the sky is full of fast, invisible traffic that somebody has to keep track of. Then that each aircraft knows where it is and says so, over and over, in a message with four parts. Then that the message travels as a radio wave, and that a radio wave is a form of light. Then that an antenna catches it, and that the round Earth limits how far. Finally that many antennas together build the map. Each lesson adds one link to that chain, and the chain is what you are assessing at the end: can a child tell the story from aircraft to map, in order, with the right reasons?

You do not need any background in aviation or radio. Each lesson below opens with the science as you need to understand it, which is one level deeper than the class will go, so that you can answer the question behind the question. If you want the full adult account, the reference course on the home page has twelve chapters; the ones that matter most for this age group are chapters 3, 6 and 7. Two things should be kept clearly in mind throughout, because they are the two places where adults most often teach something false. Radio is not sound; it is light of a colour our eyes cannot see, and the difference is the heart of lesson 2. And the aircraft is not "seen by satellites" or "found by radar" in this system: it works out its own position by listening to satellites, and then announces it. Nobody finds the plane. The plane tells.

On differentiation: the course is written for the whole 6 to 11 range, and the text of each lesson says where the younger and older ends part company. Broadly, a class of six- to eight-year-olds should get the story, the role-play, the rope and the map, and should leave able to say "planes send a message on a wave, an antenna catches it, and that makes the map". A class of nine- to eleven-year-olds can take the numbers (twice a second, 300 000 kilometres a second, a 27-centimetre wave, a 400-kilometre horizon), the idea that the message is made of yes-or-no answers, and the reasoning about the horizon, and should leave able to explain why each step is necessary.

LESSON 1

The busy sky and the talking plane

The science you need

An airliner at cruising height is about ten kilometres up and moving at roughly 900 km/h, which is 250 metres every second. At that height it is hard to see and impossible to judge: a child who spots a glint or a vapour trail has no way of telling how far away it is, how high, or where it is going, and neither does a pilot looking at another aircraft. Over a Belgian town there are nearly always several aircraft in the sky at once, most of them passing through at height on their way between other countries. To keep them apart, air traffic control needs the position, height and direction of every aircraft, continuously. The rules of separation are simple: in the airspace controllers manage, aircraft must be at least 300 metres apart vertically or several kilometres apart horizontally.

For most of the last century the way to know where aircraft were was radar: a big rotating antenna that sends out a pulse of radio and listens for the faint echo. Radar still exists, but the system this course is about turns the problem round. Every modern aircraft carries a satellite navigation receiver, the same technology as the maps in a car or a phone, and so it always knows its own position to within a few metres. It also carries a small radio called a transponder. ADS-B simply joins the two: about twice a second, the transponder sends out a short message containing the aircraft's identity, its position from the satellites, its height, and its speed and direction. The message goes out automatically, with no one asking for it and no one in particular as the addressee: it is a broadcast, like a radio station, and anyone with the right receiver can hear it. That is what the letters mean: Automatic (nobody triggers it), Dependent (it depends on the aircraft's own equipment to be right), Surveillance (its purpose is knowing where aircraft are), Broadcast (sent to everyone).

The message itself is digital. A transponder cannot send letters or numbers directly; it can only send a pulse or no pulse, and so the message is a string of 112 yes-or-no answers, each lasting a millionth of a second, whose meaning everyone has agreed in advance. The first group of them, 24 answers long, is the aircraft's permanent identity code, given to it when it is registered, a little like a number plate that never changes. The rest carry the position, the height, the speed, or the flight's call sign, depending on the kind of message. The last 24 answers are a check: the listener does a fixed sum on the message and compares the result with the check, and if they disagree, something was garbled on the way and the message is thrown away. This matters, because over a busy airport many aircraft are talking at once and their messages sometimes overlap. The height in the message is not measured by satellite but from the air pressure outside the aircraft, which falls steadily as you climb; this is the same reason your ears pop in a lift or a mountain tunnel, and older children enjoy the connection.

How to teach it

Begin with the sky, not the system. Ask who saw an aircraft this week, where, how high they think it was, and how a pilot could possibly know where they are with no roads. Let the guesses run; "the pilot looks out of the window" and "there's a map" will both come up, and both are half right. Then put the live map on the projector, zoomed to the town, and count the aircraft together. The gap between what the class expected and what the map shows is the hook for the whole course, and it is worth lingering on: every one of those symbols is an aircraft that is talking right now.

Now tell the central story in one breath, because children remember a story better than a definition: the plane always knows where it is, because it listens to satellites far above it; and twice every second it shouts out, to nobody in particular, "this is who I am, this is where I am, this is how high, this is how fast". Nobody asked it. It never stops. And everyone with the right kind of ear can hear it. With six- to eight-year-olds, that sentence, repeated and then acted, is the lesson. With nine- to eleven-year-olds, go one step further and explain that the shout is made of yes-or-no answers, that 24 of them spell the plane's name, and let them work out (with help) that 24 yes-or-no answers give about 17 million different names, more than enough for every aircraft ever built. The point to land is that the plane is not "watched": it tells. Say it both ways, "nobody finds the plane, the plane announces itself", because the opposite idea is deeply rooted and will resurface in lesson 4.

The demonstration is the control tower game, and it is the single most valuable half-hour in the course. Tape a grid on the floor, five squares by five, lettered along one side and numbered along the other. Half the class are aircraft; each has a card with a call sign, a height and a speed. They walk slowly across the grid, and every few steps each one announces its message aloud: "DTA12, square C3, ten thousand metres, fast". The other half are the control tower, each with a paper copy of the grid, and they must draw every aircraft where it says it is. Then swap. Then, and this is the part that teaches, run it again with the aircraft allowed to speak only once a minute. The towers' drawings fall apart; the aircraft have moved squares before anyone knew. Ask the class why real planes talk twice a second, and they will tell you.

With the older group, add a second variation: two aircraft announce at exactly the same moment, and the tower must record what it heard. It will have heard a muddle. Explain that this is why the real message has a check at the end: a muddled message fails the check and is dropped, and the plane repeats itself half a second later anyway. Children who have been the tower understand immediately why both the repetition and the check are needed.

What children get wrong, and what to say

The commonest wrong idea is that satellites look down and see the planes, or that radar finds them. The correct picture is that the plane listens to the satellites to find itself, and then speaks. A useful way to put it: the satellite is like a church bell striking the hour; it tells everyone the time, but it has no idea who is listening. The second wrong idea is that the pilot sends the message. Nobody does; the transponder sends it by itself from the moment the aircraft starts to move. The third is that the message goes to "the airport". It goes to everyone: other aircraft listen too and use it to keep clear of each other, and so does any antenna on any roof, which is where lesson 4 will end.

LESSON 2

Invisible light: what carries the message

The science you need

The message leaves the aircraft as a radio wave, and the one idea this lesson must establish, because the whole of physics at secondary level builds on it, is that a radio wave and a beam of light are the same kind of thing. Both are electromagnetic waves: ripples of electric and magnetic force travelling through space, needing no air or material to carry them, at the speed of light, which is very nearly 300 000 kilometres every second. What makes one such ripple red light, another blue, another a radio wave, is only how rapidly it oscillates, its frequency. Our eyes respond to a narrow band of frequencies, which we experience as the colours from red to violet. Radio oscillates far more slowly, and so eyes cannot see it, exactly as ears cannot hear a dog whistle. The aircraft's message is sent at a frequency of 1 090 million oscillations per second, which is very fast by human standards and very slow by light's: green light oscillates about half a million times faster.

Because every electromagnetic wave travels at the same speed, the frequency fixes the wavelength, the distance from one crest to the next: in one second the wave travels 300 000 km and completes f oscillations, so each oscillation takes up 300 000 km divided by f . For the aircraft's wave that comes to 27.5 centimetres, roughly the length of a school ruler. For green light it is about half a thousandth of a millimetre. For an FM radio station it is three metres. That number, 27.5 cm, is the one the class will meet again in lesson 3, because it decides the size of the antenna.

The confusion you must prevent is between radio and sound, and it is worth understanding why it is so common. A "radio" in everyday speech is a box that makes sound, so children (and many adults) assume radio waves are a kind of sound travelling through the air. They are not related at all. Sound is a pressure wave: air molecules bumping their neighbours, which bump theirs. It needs a material to travel through, it moves at about 340 metres per second, and in a vacuum there is no sound. Radio needs nothing and crosses the empty space between a satellite and the aircraft; it travels nearly a million times faster than sound. If an aircraft 20 km away makes a noise and sends a message at the same moment, the message reaches you in about 67 millionths of a second and the noise about a minute later. Children know this delay from thunder and from watching a distant football being kicked, and that knowledge is your best ally.

How to teach it

Start from what they know: things that exist but cannot be seen or heard by us. Dog whistles, the bee's view of a flower, the remote control that "sends something" to the television, the Wi-Fi in the building. Then make the claim plainly: the plane's message rides on a kind of light that our eyes cannot see, and a torch and the plane's radio are cousins. Switch a torch on and ask where its light is: everywhere in the room, at once, with no delay anyone could notice. Then the key sentence for the younger group: radio is a colour our eyes cannot see, and it is passing through this room right now, from every plane within 400 kilometres, and we cannot feel a thing. Many children find this slightly thrilling, and it is true.

The rope demonstration gives the idea of a wave a body. In pairs, one child holds a rope still and the other shakes the free end. Slow shaking produces a few long, lazy waves along the rope; fast shaking produces many short ones. Have them measure the distance between crests with a metre rule in each case and notice the rule: the faster you shake, the shorter the waves. This is not a loose analogy but the actual relationship, because the wave's speed along the rope is fixed by the rope and so frequency and wavelength trade off exactly as they do for light. Tell the class that the plane's wave is of the long, lazy kind compared with light, and that from crest to crest it is as long as a ruler. Lay the ruler on the floor beside the rope wave and let them see it. With the older group, write the rule: speed = frequency times wavelength, and let them check it on the rope by counting shakes per second and measuring crest to crest. Then give them the aircraft numbers and let them see that 300 000 km per second divided by 1 090 million per second is 27.5 cm; they will not do the division unaided, but they can follow it on the board and it makes the number theirs.

To separate radio from sound, run the fastest-messenger race. A line of children passes a whispered word from one end of the hall to the other; time it. Then flash a torch from one end and have the far end raise a hand; no measurable delay. Discuss why: sound has to be passed from each bit of air to the next, like the whisper from child to child, and that takes time; light does not need anyone to pass it on. Then, and this is the moment to be explicit, say that the plane's radio message is like the torch, not like the whisper, and that the engine noise of a plane you hear is like the whisper, arriving long after the plane has moved on. The older group can be given the numbers, 340 metres a second against 300 000 kilometres a second, and asked how many times faster light is; the answer, nearly a million, is satisfying.

What children get wrong, and what to say

The sound confusion has been dealt with above and will need repeating in lesson 3 and lesson 4; expect "the antenna hears the plane" to slide back into "the antenna hears the noise". A second confusion is that radio waves are "in the air" in the way smells are, drifting about; they are not carried by the air at all and would travel just as well through empty space. A third, from the older group, is to think faster shaking makes the wave travel faster; it does not, it makes the waves shorter, and the rope shows this if you let them watch a single crest travel. Finally, if a child asks why we cannot see radio when it is light, the honest answer is that our eyes are built for the colours that the sun gives most of and that pass through air best; radio was there all along, and we only noticed it when we built metal eyes for it, which is lesson 3.

LESSON 3

Metal ears and the round Earth: how the message is caught, and how far away

The science you need

A radio wave passing over a piece of metal pushes the electrons in the metal back and forth in step with its oscillation. That tiny alternating current is the "hearing"; a receiver connected to the metal amplifies it and reads the pulses off it. The push is strongest when the piece of metal has the right length for the wave: a rod that is a quarter of a wavelength long, standing on a flat metal surface, responds to the wave the way a swing responds to a push timed to its own rhythm. For the aircraft's 27.5 cm wave, a quarter is 6.9 cm, and that is why the real ADS-B antenna, on the aircraft and on the ground, is a short stub only a few centimetres tall. It is a tuned ear. A wire of a quite different length still picks up something, but much less, and the class can be told truthfully that the model they will build is the right size for the real thing.

How far away can the ear hear? Two things limit it. The signal gets weaker with distance, because the aircraft's transmitter spreads its energy in every direction and the fraction that reaches a small antenna shrinks as the distance grows: twice as far, a quarter as much. But before weakness becomes the problem, geometry does. Because radio is light, it travels in straight lines, and because the Earth is a ball, a straight line from an antenna on a roof soon runs into the ground. An aircraft can be heard only while there is a straight, unobstructed line between it and the antenna. The higher the aircraft, the further away that line can reach before the Earth gets in the way, and the higher the antenna, the further again. The arithmetic (the distance to the horizon in kilometres is about four times the square root of the height in metres) is for the secondary course; for yours, the result is enough: an aircraft ten kilometres up can be heard from a rooftop more than 400 km away, further than Brussels to Paris and back, while an aircraft just taking off 50 km away may be hidden entirely behind the curve of the Earth. This is why antennas are on roofs, masts and hills, and why the same antenna hears high aircraft from far away and low ones only when they are close.

How to teach it

Open with the question lesson 2 left hanging: if radio is a light we cannot see, what can? The answer is a metal ear, an antenna, and the first thing to do is find some. The Wi-Fi box has stubs or hides them inside; the car outside has a fin on its roof; every phone has one hidden along its edge; the school roof may have several. Send the class, or go yourself with a photo, and make a list. Ask what they have in common: they are metal, they are a particular shape and size, and they are very often up high. Both of those observations are the lesson, and you can promise to explain each.

For the size, build the model antenna. Each child cuts a strip of card 7 cm long and about a centimetre wide, wraps it in aluminium foil, and stands it upright in the middle of a square of card also covered in foil. Be honest about what it is: it is the right shape and the right size for the aircraft's wave, and a real receiver uses exactly this shape, but on its own it cannot decode anything, because catching the wave is only the first step and the reading of the pulses needs a radio and a computer (which the secondary course builds). Then explain the size with the swing: a swing goes highest when you push it in time with its own to-and-fro, and the metal rod "swings" best, electrically, when it is a quarter of the wave long. Lay

a 27.5 cm ruler beside the 7 cm rod and show that the rod is a quarter of it. The older group can measure and check. The foil square underneath is the mirror that completes the ear, and it is fine to say so and leave it there.

For the height, go outside, and take the question with you: why are antennas up high? Stand a child at one end of the playground crouching, then standing, then on a bench, and ask what they can see at the far end each time; something hidden behind a low wall or a parked car appears as they rise. Then make the leap to the Earth: the ground itself is curved, like the top of an enormous ball, and anything far enough away is hidden behind that curve, like the hull of a ship that has sailed over the horizon while its mast still shows. An antenna on a roof is standing on a bench. An aircraft high up is a ship with a very tall mast. Draw it on the board as a circle with a stick on it and a straight line grazing the circle: everything above the line can be heard, everything below is behind the Earth. Nine- to eleven-year-olds can then be given the real figures and asked to compare them with distances they know: 400 km is further than Brussels to Paris and back; 50 km is about the width of the province.

If there is time, a small demonstration of weakening with distance earns its place: a torch at the far end of a dark hall lights a sheet of paper faintly; brought to half the distance, it lights the same sheet noticeably more than twice as brightly, because the beam has spread over a smaller area. Older children can be told the rule, half the distance means four times the brightness, and the connection: the plane's radio spreads out the same way, which is why a sensitive receiver is needed for the far ones.

What children get wrong, and what to say

Children often think a bigger antenna must be better, as a bigger ear would be. For this wave it is not: the right size is what matters, and the right size is small. They also think antennas are high "to be nearer the planes"; the distance up is trivial compared with the distance across, and the real reason is the curve of the Earth, which is a more interesting answer. Finally, the sound confusion returns here in the form "the antenna hears the plane's noise". Pick it up every time: the antenna catches the invisible light, not the sound, and it would catch it just as well from an aircraft that made no noise at all.

LESSON 4

The map: how many ears make one picture

The science you need

A single antenna, with its receiver, decodes the messages it can hear and so knows the position, height and identity of every talking aircraft within its horizon, a rough circle a few hundred kilometres across for high traffic and much smaller for low. To see a whole country, many such receivers are needed, spread out so that their circles overlap, and each sends what it hears over the internet to a central computer. That computer does two jobs. It merges: a high aircraft is usually heard by ten or twenty receivers at once, and the same message arriving from all of them must be recognised as one aircraft, not twenty. And it checks: if one receiver reports a position that every neighbouring receiver disagrees with, that report is probably a decoding error and is set aside. The result is the live map, updated every second, built entirely from what the aircraft said and the antennas heard. Air traffic controllers see a similar picture, with radar added as an independent second opinion, since a system that depends on the aircraft telling the truth needs one.

The map shows only aircraft that are talking. Nearly all airliners are; many small private aircraft, gliders and balloons are not required to be, and military aircraft often choose not to be. So the map is honest but not complete, which is a worthwhile thing for a child to learn about any map, and a natural way to end the course on a question rather than a full stop.

How to teach it

Return to the floor grid from lesson 1, but now the towers cannot hear everything. Place three or four "antennas" (children with paper grids) at the corners of the room and tell each they can only hear aircraft in their own half or quarter of the grid; aircraft announce as before. Then ask the antennas to bring their sheets together and lay them side by side. The combined picture has every aircraft on it; each single sheet has only some. Some aircraft appear on two sheets, and the class must agree these are the same aircraft, not two. That is the whole of the merging job, done by ten-year-olds in five minutes, and it fixes the idea that the map is a jigsaw of many listeners.

Then make it real. Put the live map on the projector, zoomed to the school, and give each group one aircraft to follow for ten minutes: its call sign, its height, its speed, where it came from and where it is going. Have them fill in a card for it and pin the card to a wall map of the region at the place where it was when they last saw it. While they work, connect what they are seeing to the chain of the course, sentence by sentence: that aircraft is talking twice a second; its message rides on invisible light; an antenna on someone's roof, within 400 km, caught it; that antenna sent the message to the computer that draws this map; and that is why you can read its height on the screen. Ask the class to tell the chain back to you in their own words; this is the assessment, and most of the class should be able to do it by now.

Close with two questions. What would happen if an aircraft stopped talking? It would vanish from the map, though the controllers would still have radar. And are all the planes in the sky on the map? No, and the discussion of which ones are missing, and why someone might not want to be seen, is a good place to leave a class that has understood that a map is made of measurements and is only as complete as its listeners.

What children get wrong, and what to say

The idea that "the satellites make the map" returns here with great persistence, because the map is on a screen and screens come from the internet and the internet, in children's minds, comes from space. Take it apart gently: the satellites only tell the plane the time; the plane works out where it is; the plane says so; the antennas on roofs hear it; the computer draws it. Every step is on the ground except the first, and the map would work just as well if the satellites were replaced by anything else that let the plane find itself.

Assessment: can they tell the story?

The course has one learning outcome with four links, and the assessment is simply whether a child can tell the chain in order with reasons. Ask each child, or each group, to explain how a plane gets onto the map, and listen for the four links: the plane knows where it is and says so, over and over, without being asked; the message travels as a radio wave, which is a light our eyes cannot see and nothing like sound; an antenna, a tuned metal ear, catches it, but only from aircraft above the curve of the Earth; and many

antennas together, sharing what they hear, make the map. A six- to eight-year-old telling it as a story with the four steps in the right order has met the outcome. A nine- to eleven-year-old should also be able to give a reason at each step: why twice a second, why light and not sound, why 7 cm and why high, why many antennas and not one.

The student's page ends with a short quiz the class can take on a tablet or by show of hands; the answers, with the reasoning you should expect, are these. A plane sends its message about twice every second, because in a minute it would have moved 15 km and the map would be useless. The message does not contain the passengers' names, only the aircraft's identity, position, height and speed. A radio wave is a light our eyes cannot see, not a sound, because it needs no air and travels nearly a million times faster. An antenna is put on a roof so that its straight line of sight reaches further over the curve of the Earth, not to be nearer the planes. And the map needs many antennas because each can only hear a circle of sky a few hundred kilometres across.

A school that would like to host a small receiver on its roof, so that its own patch of sky appears on the live map and lesson 4 ends with the class's own antenna, will find everything it needs on the Become a feeder page.

NEXT

A receiver on the school roof

The four lessons end naturally with a receiver that belongs to the school. The hands-on workshop is the complete guide: the parts and their price (100 to 150 euros, or an existing Raspberry Pi), the antenna to choose and where to place it, how to prepare the computer and install the Dataero feeder, and the measurements a class can make with it over a year. A school station appears on the public map under the school's name, and its dashboard answers 'what is that plane?' every day of the year.

Open the hands-on workshop <https://radar.dataero.eu/learning/workshop>