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EPISODE TITLE

Under the Radar: Living, Breathing Detection Signals

PODCAST SUMMARY

Radars keep us informed - whether it be day-to-day, allowing us to predict the weather, or warning us of potentially catastrophic large-scale threats looming out in space. Western University Physics and Astronomy Researcher Wayne Hocking has spent his career operating radars at every point in their lifespan — from design, to research, and eventually leading to an environmentally friendly clean up. Listen to learn about the challenges of producing radars all around the world, the surprising singularity of Ontario's geography, and how radars evolved in our culture.

INTERVIEW

Henry Standage 0:29
Hey, welcome to the Western science speaks podcast. I'm your host Henry Standage and today, we are talking about radars. The all-important detection signals that warn us of looming long-term threats, and keep us informed on things like the weather, day to day, Wayne Hocking, a researcher from Westerns Physics and Astronomy Department builds radars all around the world. Wayne handles every aspect of his research, from buying second-hand PCs to run the radars on, to building the radars on location, obsessively observing their results, and cleaning it up when he's done. So, who better to have on? We talked about the challenges of producing radars all around the world, Ontario's wonky geography and the evolution of radars in our culture. Here we go.

All right, to begin, what are some of the things radars are consistently and reliably good at?

Wayne Hocking 1:32
They're very easy to control, they don't have the finesse that's required to run, say, a laser, or LIDAR or something like that. They can usually run 24 hours a day, seven days a week, 365 days a year. And I think that's the appeal. They don't need a lot of onsite technical support - once you've got them running, they tend to be fairly self sufficient. They can do a wide range of things. As far as disadvantages go. I guess one of them say compared to a satellite is that they're in a fixed position. So, they can give a lot of information at one location, but they don't move around. On the other hand, we compensate for that by having a lot of these radars around the world, which is why install a lot of them at remote sites. So, a signal from a satellite, which has relatively poor resolution that can circle the globe on a sort of continuous basis. We can sample one particular spot with very, very good quality data 24 hours a day, and we compensate by using other areas around the world whereas a satellite can cover as large portion of the world but of course, it can only be in one place at one time. So often the data from a satellite is spaced apart by 12 hours or six hours or wherever the orbital time of the flight is.

Henry Standage 2:53
So, what deficiencies do your radars overcome? In an artistic sense what is your signature?

Wayne Hocking 3:00
Firstly, when you design a router, you've got to choose the frequency and the frequencies depend on what you want to look for. As for my radar, specifically, things that we do, I use a very detailed analysis method to determine winds, which is probably more sophisticated than most radars use. We can measure the strength of turbulence with our radars, which very, very few radars can do very well, around the world. Even ones working in frequency don't do a very good job of getting turbulence. I think we've got the best one. And we know that we're fairly well regarded in that regard because NASA contacted us for consultancy with regard to Space Shuttle Columbia back in

2003. So, we know we have a good reputation. The main thing we do that's unique is the turbulence measurements - the winds, everyone can do that. But again, we have very different type of software, which gives us a higher quality data, I think,

Henry Standage 3:52
What are some of the different locations you have had your radars placed around the world?

Wayne Hocking 3:58
It depends on the frequency. We basically have two main classes of radars. There are the meteorological radars, which are designed to measure winds from pretty much ground level up to maybe 10 or 15 kilometers in altitude. Some of the largest traders like this can get to 25 kilometers but we can't afford to produce to have transmitters that powerful and most of those we've built are in Canada. We have a network here, which covers a fair chunk of Eastern Ontario and some of Western Quebec. The other type of radio we have is a meteor radar. It's designed to measure meteor trails as they come into the atmosphere. Regional physics is an interesting area, it pretty much died out in the 1970s, people thought they'd done all they could with it. And it was replaced with other techniques but in 1999 when I came to Canada I decided to reinvigorate the technique, the main reason was because it's the cheapest radar you can build and I didn't have very much money so I thought I'd go back to square one and look at meteors and in doing so we worked out some techniques which hadn't been applied before. In the past a typical meteor radar, would detect 400 meteors a day. We modified the design substantially. And even though the radar only cost a few 10s of thousands of dollars, we were able to detect 2000 meteors a day. And as time went by, we've improved that and improved that to the point where we can now measure, not with my radars, but other radars, which I've helped to design and build, 30 to 60,000 meteors a day, which is a huge number of meteors. And that improvement in technology has encouraged a lot of other people around the world to then develop Meteor radars as well. We use Meteor radars, for a variety of reasons. One is to study the meteors themselves. But the other is, when a meteor trail comes into the atmosphere, it burns up and leaves a trail of ionized particles. And this is what the radar sees the trail. And the trail gets blown by the wind. And so, by combining all the information we have from all of these different meteors that occurred during the day, we can determine the winds and even the temperatures in the height region between 80 and 100 kilometers in altitude. The consequence of that is then we can measure winds at these heights which are very, very special and very unique. At ground level, you're used to the weather in Calgary being different quite different to the weather here. At upper heights, the weather around the world isn't the same, but it's very correlated. So, to make our measurements of winds, we measure things called atmospheric tides, which are very similar to tides in the ocean, but have significant differences. And various types of waves which propagate in very, very large amplitudes. At these heights, and to make use of them, we have to compare with other measurements all around the world, places like Norway and Sweden and Russia and Japan and Alaska and then in the southern hemisphere as well. So, the best way to analyze these is a true global model. And that is one of the unique things about the meteor radars that we use is the absolute need for an interdisciplinary, broad global study to make the best value out of it.

Henry Standage 7:05
Yeah, I saw recently that the Government of Canada announced that they would be installing 27 new radars by March 2023. What does expanding a radar network mean for a country's government and what they're trying to do?

Wayne Hocking 7:23
For them, it's a very different situation, they have to find the land, they have to spend large amounts of money to bring big contractors in and they flood pouring concrete and, it's a fairly heavy duty thing it’s like if you decided to make a new building, my radars are quite different mine are very portable and very mobile. And I can basically set up a radar in two or three weeks and have it running. But I don't have the financial resource, of course that the Government of Canada has so that's the sort of trade off.

Henry Standage 7:56
What's the most challenging location you've ever had to install and design a radar?

Wayne Hocking 8:01
Ah, well, every site has its own different problems. And they always catch you by surprise. Now, this is another difference where between, say a government installation, and my installation. In the case of the government, they'll spend a long-time planning and preparing and leveling the ground and going through every possible thing that could go wrong. And if something doesn't look right, they have a lot of money to throw at it and fix it. In my case, we have very limited funds. So as an example, I'll give you some examples of situations from when I installed a couple radars in Brazil. In Brazil, radars are typically $200,000 a year to build up. So, I had to still install a site in a place called Karori. I had to install two radars in Brazil at the same time, I did one in a place for Santa Maria. And then I flew up to the north, to do one in Karori. And we always installed them on flat ground that was one of their criteria. And when I arrived at the site, it had no internet. It was basically a cement building and nothing much more. We had no access to the outside world. And they'd given me the side of a hill basically to put this instrument on and there was nowhere else I could put it. So, I've never done that before. So, on the fly, and we had no access to the internet on the fly, I had to go back in my mind through my previous derivations and try and figure out how to do a three dimensional rotational transform of the data. I had to put all the antennas on the side of the hill, derive this from scratch because it's not difficult, but it would have been easier to look it up in a book, but I didn't know this was going to happen. And then I had to integrate it all into my software all in 24 hours. And so that was a surprise and it really threw us for a bit of a loop, but we were able to handle it. So, we often have found ourselves dealing with situations like that where we had to function very quickly on the fly. And as a corollary to that, a couple years later, we installed a raider for the Brazilians in Antarctica, and this had a couple of interesting consequences. Again, they promised us flat land. And it turned out we didn't have that land. But basically, what happened was we got to Punta Arenas, where we're leaving from, we had all the radar equipment there, which is quite large amount, probably a tunnel or more of equipment. And they told us, you can't send the material like that it has to be broken down into packages, less than 70 pounds in weight. And it turned out the reason for that is they have to vary all the equipment in by rubber dinghy from the from the ship, to the land, and we were not told any of the about this, we are 24 hours till the flag took place. And then, so we found a workshop around Punta Arenas and worked like crazy, we pulled the entire transmitter and receivers assembly apart, broke it down into 70 pound chunks, build boxes for it, put it all in the boxes and put it on the Hercules aircraft for shipping down there. Then we found that the aircraft was actually full, and they hadn't properly prepared for us. And they had two pallets, one with food for the people at the station, and one with our equipment, and they said we're going to have to leave your equipment behind, we can't take it. I said, well, we've been spending a year preparing this. So we negotiated with them. And in the end, we agreed that we'd send our pallet, unpack their pallet of food, and repack all the box of food around our equipment, so we could fit both of them in the in the aircraft. And so that was the more innovation we needed, they were very good and very cooperative. And we did eventually get everything down there. And then when we finally got there, we had to unload everything and put it under these rubber dinghies twice once to put it onto a ship and then take it off the ship again later. And then when we finally got the equipment down to the site, which they had assured us was flat land, it was actually the side of a rather steep mountain and not flat at all. So that required a lot of innovation about the way we set it up. We could no longer use some of the strategies we plan for putting up the post, we had to build things called gabions out of wooden boxes, we had a mountain on the side of the hill. And so, software I'd written several years earlier for having equipment on the side of the hill then came into play. And so, we had a frantic five weeks basically, adapting to a whole bunch of things that we weren't properly informed of. So that's a typical sort of case. Sometimes it goes smoothly, sometimes not so smoothly. But we do a lot of things on the fly to make it happen.

Henry Standage 12:26
Your works also gone further than just Earth. Looking upwards, how are you able to measure meteors at a higher rate. And what does that unlock?

Wayne Hocking 12:36
As I mentioned before the meteors leave ionized trails behind them, which the radar signal then reflects off. And the major purposes are to measure winds and turbulence and temperatures in the upper atmosphere on a continuous basis, the way we made it so that we can measure more meteors than anyone else was to change the sampling strategy, we use the process called aliasing, which is usually a bad thing. But because we understood it, we were able to turn it on its head and and mean that we could transmit at a much higher pulse repetition

frequency than had been used in the past. In the past, people only transmitted 400 pulses a second, typically, we were able to transmit over 2000 pulses per second, which gives us what we call an ambiguity in height, we don't know what height it comes from. But because we know where Meteors are, we can some work out where each should be and therefore, we can get much higher resolution than had been previously possible. And as I say that became a standard for quite a large number of years, as far as applications go. And the main occupation for the moment is, is measurement of the winds and understanding tidal motions and gravity waves in these high heights. But we also measure temperatures. Measuring temperatures, we've actually found some interesting zones, at these heights where the temperatures are so cold, that superconductor engines could work there. And so this has important implications for example for space travel, and we may talk about that a little later on.

Henry Standage 14:06
Such a large part of what radars do for us is give us a pair of eyes that measure things that we can't actually see with our own. So, what are the some of the things that would surprise us that radars pick up, that are existing out there in the world every day?

Wayne Hocking 14:21
One example which people seem to respond to, is on a perfectly clear day when there's not a cloud in the sky. Our radar still pick up turbulence strings and we can measure the winds from ground level up to 15 kilometers, even on a day without any clouds in the sky at all. Nothing visible, just the sun and the blue sky. But our radar sees all sorts of turbulence going on which you can then use to determine the wind. I build radars that's just sort of the tip of the iceberg. I enjoy building them. It gets back to my roots. So, I like working out in the outside. To me working on a radar, it's quite physical, but it's a bit like going to the gym and doing gardening at the same time, it's a pretty nice pleasant sort of situation to be in. But in any field, I take up, I spend a lot of time just getting the background of what I'm measuring, so I don't just build them and then walk away. And so, I'm fairly well versed in turbulence theory and meteors and so forth. And the fact that I have a significant background in turbulence, I've done quite a lot of development of basic understanding of turbulence and how turbulence applies to the atmosphere, irrespective of the radars. And in 2003, when the space shuttle Columbia blew up, I was the first person that NASA contacted when they wanted to understand what might have happened to the aircraft, from the point of the atmospheric effects. So, I worked for them for several months writing reports for them explaining what turbulence is like in the upper atmosphere, because they didn't have as strong a background as perhaps they could have. And so, I think there's about five reports that I wrote, which are sort of now classified down at NASA somewhere, which they refer to, for these studies. And so that was actually quite productive, and they were appreciative of what I did. And I learned some stuff as well, that was part of the reason I ended up as a Fellow of the Royal Society of Canada was because of the unique work that I did with NASA for dealing with this turbulence. And so, any field I mean, I also very heavily invest in understanding the dynamics and the basic atmospheric motions and stuff so that I can go with it. So, I'm just I'm not just a construction guy. I do work in theory, and practical applications as well.

Henry Standage 16:42
I think people don't really have a clear idea of what, after you've built the radar, what observation and that process is really like, I was wondering if you could kind of take us a little bit behind the curtain and tell us once the radar is built, what observing it is like day to day because I think most people imagine something showing up on a radar, oh my goodness, it's Armageddon, or whatever. But what's it really like, after it's been built?

Wayne Hocking 17:11
Well, we do keep our eye out for odd strange events. But most of the time we don't, that's not our main goal, we are measuring turbulent strengths. And what we call radial velocity is the speed at which the turbulence is moving through the atmosphere, every minute of the day, the beam is just automatically moving around through different regions in the sky, it doesn't move physically, antennas roll up in place, by changing what we call the phasing of the antennas, we can point it to different regions of the sky. And so, the system basically just cycles around and around and around, continually measuring these velocities. And then we combine, and we have a lot of online software for forming winds, temperatures, temperatures in the upper atmosphere.

Henry Standage 17:51

Ontario represents a really interesting location because it features some of the lowest latitudes for low temperature place on Earth. What does this phenomenon mean?

Wayne Hocking 18:02
When you say low temperature, you're talking about the atmosphere, you're talking about the region between 80 and 100 kilometers. Underground, obviously, Ontario is fairly typical worldwide. But what happens with the meteor work and other work we do is, I should mention, sometimes this is particularly true in the Arctic and the Antarctic, the normal radars that we use for studies of the troposphere also have a rather unusual feature in that in summertime, they get echoes from a height of 80 to 90 kilometers altitude, so very, very high. This is where meteors spend most of their time. But normally, we don't see anything there. We don't have enough strength for these tropospheric radars to see the Meteor. And the key thing is that it requires very, very cold temperatures for these to occur. And so we can use our Meteor radars to determine the temperatures because the meteor radars are measuring exactly the same height as these AP radars, which are normally used for lower atmosphere measurement, but can be adjusted just in summer, to these very, very strong scatters. Now, why its important is because these temperatures are very, very cold. And we can see them in Ontario, which is very unusual. And the reason we can see them in Ontario is because of something called the geomagnetic field, the magnetic field of the earth. And it turns out, there's an area called the auroral zone, which actually bends and twists around because the magnetic field is not perfectly symmetric. And there's a low point for this route, what we call a rural oval in Ontario up around campus casing and Abitibi Canyon.

Henry Standage 19:38
Why don't we talk about how radar building can go wrong? What are some of the situations you found yourself in?

Wayne Hocking 19:45
I remember one instance in Sumatra in Indonesia. We were building a meteor radar for the Japanese and it wasn't quite working. Some measurements weren't quite working out the way they should. And I was thinking about it, was about eight o'clock at night. The sun had set, this is the equator, so the sun sets at six pretty regularly. And I suddenly had a thought of what might be the problem. So, I grabbed the torch and started running outside. And I came a couple 100 meters. And then I had the Japanese people following me running like crazy saying, wait, wait, come back, come back, come back. I said, wow, I think I know what's going on. And they said, Wayne there are Tigers out at this time of night, we don't come out in the back. So, one Tiger sounds like a pretty good reason to go back inside. So, these sort of things happen all the time, we've been surrounded by Wolf packs.

Henry Standage 20:31
So, looking forward the next 50 years, where can radars go from here?

Wayne Hocking 20:38
There was a very strong activity of meteors between 1950 and 1970. And that was a major research. And then in 1937, as people stopped doing it, there were other systems that replaced them, which hadn't been anticipated, and died out into nothing. And then 20 years later, in 1990, the whole method was reinvigorated. So, it's hard to know where you're going to go. I would imagine that as far as radio communications go, probably the next big thing will probably be renting radio communications on the moon, perhaps so that we can communicate with spacecraft, traveling back and forth to Mars. I don't know how soon that's going to happen. But I don't think we're going to be able to stop ourselves going to Mars and some of these other planets, at least as outlier stations. Certainly, Elon Musk has plans of doing that and it's certainly possible. A lot needs to be done in the meantime but it's amazing how fast things go. As far as measurements down on earth go. A lot of that is driven by the need. So, at the moment, there's not a lot of people working in my field, because we do it mainly for curiosity. But if it got to the stage where it's, for example, the superconducting engines that I discussed before became mainstream, then knowing winds and turbulence at 80 to 100 kilometers would become as important as knowing the winds in the stratosphere these days. I mean, 50 years ago, no one cared what the winds were in the stratosphere because we just lived in the troposphere. And then suddenly, jet airliners came along. And the stratosphere was interesting, and suddenly crucial. And even now, people don't fully understand the stratosphere as well as they could. But we need weather forecasting because that's where the aircrafts fly. And so if this idea that, that if suborbital flight

becomes the norm, which I think it will, because we're causing a lot of pollution in the stratosphere, a lot of the pollutants produced by high flying aircraft are very damaging to ozone in the stratosphere. So suborbital makes a lot of sense pollution wise, because we're up way up into space where hopefully, we won't be causing so much pollution. Of course, we have to use something to boost us up there in the first place. But if, for example, suborbital became the main way that people travel around the world, then suddenly knowing upper atmospheric winds at 80 to 100, kilometres could be really, really important. And we would have laid the groundwork for it. But suddenly, you'd have 10 times as many radars and probably with 10 times the power because now there's a need to have it. Suddenly it becomes commercial. When we build radars we build them with the cheapest things we can find. I run most of my readers on old computers, XPS and that type of thing from the 2000s. Because I can go down to a cheap store and buy a $200 computer, when some cost $2,000, and run my radars effectively, often. So, most of my radios run out very, very old equipment, which I modify, and upgrade and do various things too. And so, we live on nothing to get our equipment running. But when the interest comes to study these upper levels, there'll be a whole new class of instruments, these will be multi million-dollar things, $50 million system systems all around the world, measuring 100 times as much as we can measure. But as I say, it's not ready yet,

Henry Standage 23:59
If you've ever lost your phone, Apple has this great app called Find My iPhone and you can add friends on it and figure out where they are within your city. So clearly, iPhones have their own internal radar of some sort. So, what would the distinction be between the radars you build and the ones that are present in our phones and other devices of that sort?

Wayne Hocking 24:23
Mainly power. And I'm talking radars, which are kilowatts, megawatts, you're talking at most a few watts, probably milliwatts, a few hundred milli watts in most cases, and directionality. You work out where your friends are by because they work out where their nearest IP is, where their nearest internet link is. Those radars work out where you are, because they can actually point, like a human eye, they can point in the direction in which the signals coming from and so they have an entirely different process. You also deal with your friends because they transmit and you transmit, you have a network to send the information back and forth. And that's another area I've worked in, which I didn't want to say too much about. But for example, when drug runners carry drugs and such like at sea, we build radar which can actually detect these ships moving out at sea. So that's another potential application, which can come out of all this. But I think the link between the iPhones and the normal radar, it's difference in power, the different way it's doing operation, we're dealing with passive targets, you're dealing with active communication rather than looking for targets.

Henry Standage 25:33
This is my last question. So, a really admirable facet of your research is how, when you leave a radar location it usually looks exactly how it did before you arrived. So how are you able to build radars in an environmentally friendly way. And when were you able to start accomplishing that due to some of the modern technologies available?

Wayne Hocking 26:00
To do the work that I needed to do, I knew I needed a lot of radars. So, I need to have two things, I needed to be very efficient to put it together. And I need to be able to pull it apart. And most people when they build radars, are at four big heavy foundations, there's concrete, concrete trucks coming in, there's tractors involved, we burn a lot of heavy equipment. Because I didn't have any help to support me. Everything I did had to be done by hand. Now when I build a radar, one of the larger tropospheric ones, I have to lay three kilometres of coaxial cable by hand, I have 150 antennas, which I have to make out of the looms. So that gets many, many hundreds of meters of aluminum and I have to cut it down to put on thousands of connectors. But everything has to be done by hand. And so, I developed the technique. And secondly, I knew that eventually I'd have to pull it down people. Often, I have to go on rented land or find a farmer or someone who's willing to have my land. So, I knew that I have to basically pull it out of intervention. So, we developed a system whereby we could mount all antennas on posts driven into the ground with a sledgehammer. So, it's something a human can do, we don't need to have a tractor to do it. So typically, in a radar we'll have about 340 posts, you can buy them at TRC stores driven into the ground,

we use pairs of those to mount the antennas on, the antennas are made usually in my workshop somewhere or in a basement. And everything can be broken down to basically just thin rods of aluminum, which we then reassemble on site.

We also have to build a fence around the Earth to keep wild animals out. But everything can be done by a single person. And so when we disassembled it, a) we want to keep all the parts because we may want to rebuild it again somewhere else b) we have an obligation to whoever's hosting our land to return it the way it was. And so, we made a promise to ourselves, we would never use machinery we'd never use tractors, we wouldn't use cement tracks, we wouldn't bring anything that would be impossible to remove. These things cover a circle of diameter, 50 meters or 100 meters. So, they're quite big constructions. But we've got it down to a fairly fine art.

Henry Standage 28:21
We'll finish up the interview here. But thanks so much for your time Wayne, I really did gain a whole new understanding of what radars primary function is and the appeal of building them as a researcher. So once again, thanks for your time.

Wayne Hocking 28:35
Thanks, Henry.

Henry Standage 28:38
That concludes another episode of Western Science Speaks. If you enjoyed the show, subscribe to us on Apple, Spotify and podbean by searching WesternUscience to make sure you stay up to date on the latest episodes from Season Four. You can find previous episodes of the show at uwo.ca/sci/podcast. For now. I'm Henry Standage, signing out. Thanks for listening.