Episode 207 – Hyperspectral Imagery, 1,000 Mbps from Space and a Health Monitor for the Earth

Speaker: Awais Ahmed, Founder and CEO, Pixxel – 23 minutes

John Gilroy: Welcome to Constellations, the podcast from Kratos. My name is John Gilroy, and I'll be your moderator. Joining us today is Awais Ahmed, founder and CEO of Pixxel. Pixxel is building a constellation called Firefly, otherwise known as the Health Monitor for the Earth. He is here to share his knowledge on hyperspectral imagery, how access to it can support faster responses to environmental issues, and how its data can be used to provide insights on terrestrial changes that haven't even happened yet. Welcome, Awais. How are you?

Awais Ahmed: I'm doing well. Thank you, John. It's great to be here.

John Gilroy: What a topic. My goodness! So let's start from the beginning and maybe go back a few years or put this in perspective. What is your perspective on how Earth observation imagery and data has traditionally been collected and distributed?

Awais Ahmed: Yeah. So I think when we look at our planet, there are very few technologies that would enable us to see what's happening across the entire planet, and Earth observation has been one of those. Ever since the 1990s when the first commercial imaging satellite constellation started beaming down black and white imagery, and then from there to color imagery, which is RGB, and then from there to multispectral, I think we have moved to getting better and better resolutions of data, starting with a few hundreds of meters, getting down to few tens of meters, and then getting down to sub-meter as well.

But when you look at all the problems that are plaguing our planet, whether that's climate change, whether that's global warming, deforestation, pollution, satellite imagery and Earth observation happens to be our first mode of defense against that because that is what tells us what's happening where, that tells us at a global scale how things are changing, and it gives us a new perspective that we are all one planet.

There might be different countries across the globe with artificial boundaries that have been created over many, many years, but in the end, we're all one planet, one species, and that we need to take care of it. And satellite imagery has been that first mode of defense against the problems plaguing Earth.

John Gilroy: I think a conservative statement would be that there's maybe been some changes in the last few years in areas of Earth observation satellites. So what are the drivers that are prompting a change in how Earth observation imagery is captured?

Awais Ahmed: Yeah, so I think over the last decade especially, there have been three resolutions you talk about from space that all need to get better or there has been a driver or momentum to make them better. The three resolutions are spatial resolution, spectral resolution, and temporal resolution. So the spatial resolution aspect is how much zoom do you get on the planet.

When you're talking about 10 meters or one meter or 30 centimeters, you're basically stating that what is the maximum difference on the surface of the Earth that you can see. If you're saying your spatial resolution is 30 centimeters, you're able to distinguish things that are 30 centimeters apart. Or if you're saying it is five meters, you can distinguish things that are five meters apart.

So every year, every decade there has been consistent improvement being done on can we get that resolution even better? Can we go from five to one meter? Can we go from one meter to 50 centimeter, 50 centimeter to 30 centimeter? And now there are companies looking at getting it down to 10 centimeter as well so that we can see our planet a lot more clearly. The other focus and change has been around the temporal resolution.

How frequently can you come back over a particular area and see what's happening there? And Planet Labs over the last decade or two have been able to get it to a daily revisit anywhere on the globe. So we started from once every month to once every few weeks, to once every five days, to now you're able to see any part of the globe at least every day, and some parts of the globe every few hours as well. And so that's the temporal resolution aspect that's getting better and better every year.

And finally, you have the spectral resolution aspect, which is where Pixxel comes in is you are able to see the wavelengths of light that human eyes can see. It's in the visible range. It's three wavelengths: red, green, and blue. But how about you go beyond human eyesight to the infrared side of things, be able to see those invisible problems that you can't see with normalized or normal cameras. So I would say those have been a few of the drivers that have been driving change in Earth observation, better spatial, better temporal, and better spectral resolutions.

John Gilroy: Well, Awais, I think many viewers know about hyperspace, but not many people can really define this term hyperspectral. You talked about it a little bit, but maybe we get more definition for our listeners here. So what is hyperspectral imagery and how is it different from imagery that we commonly see when we go to Google Earth and look up a city?

Awais Ahmed: Yeah, absolutely. I think that's a question we keep getting asked a lot. If I were to start with an analogy and then we'll go into the technicals a little bit, so when you have a broken bone, let's say I get into an accident and I broke a bone, I go to the doctor's office and the doctor needs to see what's actually broken or if it is broken. A normal DSLR camera or a phone camera won't tell the doctor clearly what's happening because it's invisible to human eyes.

And so the doctor would need an x-ray machine to be able to go beyond the visible spectrum to be able to see the x-rays and see what's broken. And that's very similar to MRI machines and ultrasound machines. There needs to be different kinds of instruments that show the doctor invisible things happening in the body that normal human eyesight, normal human eyes or normal cameras are not able to show.

Similarly, when you're looking at the planet Earth from space, there are three kinds of imaging basically that you can talk about. You have RGB, you have multispectral, and you have hyperspectral. Now, when we say RGB, that's just a fancy way of saying what human eyes can see. So human eyes, we can see a very bright colorful world in front of us every day. But all of that is basically your human eyes converting photons in three wavelengths: red, green, and blue.

We've all learned the different colors of the rainbow V-I-B-G-Y-O-R, but those are all basically in the visible range. And there are basically three broad wavelengths: red, green, and blue. So in a sense, human eyes are only seeing things in three wavelengths. And then you move on to multispectral, which has red, green, and blue wavelengths, but then you have a couple of infrared wavelengths as well.

But what hyperspectral is it's taking the entire electromagnetic spectrum and breaking it down into hundreds of wavelengths. So you're going from three wavelengths in human eyes to about eight wavelengths in multispectral cameras, which is what you see in space today, to hundreds of wavelengths, 300 in our case, that enables us to see invisible things.

So with a very quick example, if you are looking at a farmland with an RGB imager, a multispectral imager, and a hyperspectral imager, an RGB imager would just tell you that there's a farm here, that there's a road here, that there's water here, just like human eyes would be able to. With multispectral, you can go one step beyond that and say if the crop that you're looking at in the farm is healthy or not healthy, but it won't tell you exactly due to what reason is it healthy or not healthy.

But when you're looking at it with hyperspectral, because of the hundreds of wavelengths, you can identify nutrient content in the soil, you can identify what species of crop is growing, you can identify if there is a crop disease, all of which are generally invisible to the previous two types of modalities. So that's what makes hyperspectral special, roughly 50 times more information per image than other types of imagery.

John Gilroy: So 50 times, that brings an interesting problem that the many in the technology community are talking about is the old adage, you get 500 channels and nothing to watch. I mean, you could have 50 times information, and how much of your time do you spend prioritizing? So what do you look at? What do you not look at? I mean, it's 24 hours in a day. Even someone who works as hard as you doesn't have that much time. And so what are some of the most important environmental features that can be seen and hopefully solved more quickly with hyperspectral technology?

Awais Ahmed: Yeah, so I think the good thing is yes, it is a complicated data set. It's more complex because of the hundreds of wavelengths that are coming down, which means that much more amount of storage, that much more amount of computation. But with a lot of advances happening in artificial intelligence with cloud computing, with supercomputing, I think all of that's basically a solved problem.

If you can bring in artificial intelligence and automation to it, people don't have to sit and look through every image. They can basically only come into those parts where there might be confusion about something. So as you mentioned earlier, we are building a health monitor for the planet. And that's been our vision since day one because hyperspectral imagery has this unique capability to show us what's going wrong with our planet or what's going right.

So maybe a few examples of what we have been able to do with the satellites that we've already launched or even more satellites that we will launch. When you're looking at all the water bodies across the world, there are different pollutants that might end up being imbued into those water bodies, whether it's a lake, whether it's a river, and being able to identify if this water body source is actually healthy, is it contaminated with certain kinds of pollutants or chemicals, and identifying where are they actually coming from.

Is there a particular factory or an industry that's emitting it, or is that just a particularly poisonous algal bloom? Is that weed? Is that phytoplankton? So being able to identify what is causing a dip in the quality of these water bodies is a big use case that we have been doing with various organizations. There's a whole lot of use cases specifically around oil and gas leaks. So you have these pipelines that crisscross almost every country on the planet.

And whenever a leak happens, whether it's a invisible methane gas leak or whether there's an invisible underground oil leak because most of these pipelines can also be underground, being able to detect those subtle changes, when an oil leak happens in an underground pipeline, you can't see it with human eyes. But what it does is it changes the characteristics of the soil where the leak has happened.

And so a hyperspectral satellite can basically detect that subtle change in the chemical characteristics and identify that there is an underground oil leak that has happened here, or if there's an above ground methane leak, or if it's a sulfur dioxide leak or any other greenhouse gas leak. We've also been looking at various forests around the globe, being able to see is there deforestation that's happening somewhere? How is the species composition of trees changing?

Forests are one of the biggest source of carbon sequestration. They basically absorb all of the carbon that is being emitted and being able to identify is the carbon sequestration from the forests increasing, decreasing, how will that affect the heating of our planet in the few years and so on. So I think those are what the hundreds of wavelengths from hyperspectral enable us to see made possible with advances in computing and artificial intelligence models.

John Gilroy: I've read about gas leaks and a lot of these things are pretty good use cases, but there's always the unexpected. What's coming around the corner, you just don't know. And so it could happen. There could be an earthquake. There could be tsunami. Some bad things can happen. And so my question to you is, well, how does higher resolution, how does this imagery help relief efforts in these different response situations?

Awais Ahmed: Yeah, I think a very pertinent example is the forest fires that plagued Los Angeles, California not very long ago. What hyperspectral imagery can do is it can look at different parts of the forests or trees and identify where the moisture content might be low, so where the moisture level of the trees is normal, where the moisture level of the trees is low. And so therefore, you know where the risk of forest fires starting or where the risk of fires spreading is higher.

And therefore, when you're mobilizing resources on the ground to be able to fight the spreading forest fires, you already have at least some sense of a model that is telling you that the likelihood of the forest fire spreading in this direction is higher because this is drier and therefore it's more combustible. Of course, you need to combine it with wind data and which side wind is flowing. So I think that's where hyperspectral data combined with other data sets becomes important in natural disasters like forest fires.

And whenever there has been a hurricane or a typhoon in different parts of the world, those are predicted by different weather satellites. But once they are moving across different land masses, hyperspectral can identify and say, "Again, this part of the land is more susceptible to landslides because the soil composition has now changed. Or here is where the water is starting to get really poisonous due to a variety of different reasons. And here is where the devastation cost is the most."

So the people, again, on the ground have a map beforehand of identifying which are the higher risk areas and where do they need to, and from there, where do they need to move again. So I think just a couple of examples of where this data can help with disaster response as well.

John Gilroy: Yeah, I love hearing the use cases for a disaster response, and those are always front page news and headlines when you pick up your phone. But every day people got to go out and earn a living, and there's commercial applications as well. So let's maybe focus here on some commercial applications of this access to hyperspectral imagery.

Awais Ahmed: So I think we have a lot of agricultural customers, so companies that either deal with fertilizers or seeds or have their own large areas of farmlands. And so hyperspectral can help with identifying soil nutrient content. So you can basically look at a particular farmland and say that here is a nitrogen, phosphorus, potassium map of this land, so you can identify if there is nitrogen that is missing from a particular swath of land.

And therefore, the farmers there can go now and buy nitrogen fertilizer so as to increase the content in that area. And therefore, the crop yield can be increased and it can be made more efficient. Or we work with companies and organizations that have their own farmlands and identify if there is early signs of crop diseases or pest infestations. And this is before even the symptoms start to show up that human eyes can see.

And so when you're able to detect a crop disease starting from a particular area much before the symptoms show up, you can then go and curb that before it has spread to larger areas. So agricultural commercial use cases are quite heavy on our list of customer wish lists. And then you have a lot of mining applications. So every month we hear about different governments wanting to look at lithium deposits because of the electric vehicle revolution that's coming in, cobalt.

So there are a lot of these rare Earth metals and minerals that are now almost national security implications for different countries. They want to all have resources of these metals and minerals, so they're not dependent on other countries for electric vehicles. And hyperspectral can detect exactly which mineral is present where.

There was a very good example of this where the United States Geological Survey, they flew a hyperspectral airplane all across Afghanistan a few years ago over many, many months, and they found nearly $1 trillion worth of new metal deposits that they were not able to find previously through other sources.

Now, imagine taking this hyperspectral imagery, which they did using an airplane over many, many months over just one country and scaling that up for the entire planet, you can identify exactly what minerals and metals are present where, and therefore what the countries need to do, what we need to mine. Identifying mineral resources in areas that are far away from human settlements so that the environmental implications of that are also not harmful.

So I think those are the few commercial examples of what our hyperspectral imagery can enable beyond the environmental use cases we talked about.

John Gilroy: So Awais, I read that your Firefly constellation currently has six satellites in orbit. In fact, I saw a video this morning, we called that a flock. Six is a flock of satellites. I think it's a great phrase. So can you share with us the regions they're capturing and the ecological significance of each one?

Awais Ahmed: Yeah. We had launched three demo satellites in 2021 and 2022. These were satellites that were trying out how hyperspectral imagery and cameras would work. And with the Fireflies, those are the culmination of a lot of iteration and experimentation. These are fully commercial satellites. That means that we'll be able to serve customers across the globe.

So the thing with the six Fireflies in our constellation is that these six satellites can look at any place on the Earth every 24 hours. What that means is let's say I'm looking at New York at 11:00 AM today. We can come back and relook at New York at 11:00 AM tomorrow and the day after that and the day after that. And that hold to whether the city is New York or Los Angeles or Tokyo or London or anywhere on the globe.

You can come back and see things every 24 hours. And that means whenever something is changing, we can see that changing on a daily basis globally. That's why the commercial satellites called the Fireflies are really important from our standpoint. The significance of each of those satellites is basically that they all work together for the use cases we talked about earlier.

They help us detect leaks. They help us detect pollution. They help us detect rising carbon levels and so on and so forth. And when they work together in a flock of six, that's when the magic happens because now you have an entire planet being covered at a level of revisit that really makes it possible to see things as they happen, as they change in near real-time without having to wait to take care of something that's problematic.

John Gilroy: Capturing the world's highest resolution hyperspectral images, it sounds like... I don't know, if you think about it a little bit, you need an advanced system on the ground for receiving and processing and distributing these images. So what is the ground system like for a constellation such as Firefly?

Awais Ahmed: I mean, the challenge with hyperspectral is that since it is capturing 50 times more information or detail than normal imagery, it also has that much data and storage that we need to take care of. In space, everything is about being very judicious with your resources because there's only limited amount of power that you have in orbit. There's a limited amount of time that your satellites can communicate with the ground station. So there's a few things that we do to take care of that.

One is we compress all of the imagery onboard the satellite itself, so we can beam down a lot more of it without having to lose any information. We have very powerful radios on the satellite that beam down data at a very high speed. So usually satellites of the size that we build and launch are between two megabits per second to 50 megabits per second of speed when they're beaming down imagery from space to Earth.

Whereas in our case, it's nearing almost GBPS. So going from 50 MBPS to 1,000 MBPS makes a big difference in terms of how much data we can downlink. But what we do on the ground station side is we work with partners across the globe, folks like KSAT, folks like Leaf Space, who have ground stations spread across the globe, and we lease out on these ground stations.

And so that way when KSAT has a ground station near the North Pole and our satellites are in the polar orbit, which means that they're going over the North Pole every 90 minutes, with just one ground station antenna, we can now have 16 opportunities a day, every 90 minutes to be able to downlink that data, which would not be possible if the ground station were somewhere near the equator.

Similarly, we have a ground station antenna near Antarctica. Since it's going over the North Pole, it also goes over the South Pole. And whenever it goes over there, we can downlink the imagery there. But the ground stations are many fold. It's a very proliferated sector and commoditized sector now, and we can pick and choose where we want to be able to downlink this. And through a combination of all of the things I talked about, we're able to downlink all of this data.

John Gilroy: Well, here it is in 2025, Awais, everyone's talking about artificial intelligence. So I got to bring this in the discussion. Got to shoehorn it in somehow or other. So what about you? What about your thoughts on artificial intelligence and machine learning? It's providing these insights from hyperspectral imagery and data.

Awais Ahmed: Yeah, so I think as I mentioned, it has a lot more data than normal types of data and imagery. And so that means that you can't have people sitting there on a daily basis or an hourly basis and going through all of that imagery. You have to automate it. And the biggest help there is using AI and machine learning.

We've been doing that since many, many years ever since we started machine learning, whether that's computer vision, whether that's reinforcement learning and so on. But now, especially with large language models and foundational models becoming the norm, I think that's where the industry is also going.

So imagine one year from now, just like you would go on Google and type in and ask Google, tell me what are the different restaurants I can have Italian food around me, but imagine that now on satellite imagery, just going into a platform and typing in, tell me what is the potential yield for corn this year in the United States of America, and then the platform does everything for you in the backend and turns out the answer with all of the advances that are happening in artificial intelligence.

So basically, you would end up creating a very queryable Earth. Just like Google made the entire internet queryable, you would want to make the entire planet queryable so that everyone can get an answer to what they want what's happening on the planet on a real-time basis, whether that's pollution, whether that's yield for particular crops, whether that's disaster response, and so on and so forth.

So I would say that's where AI and ML will play a very key role. But even without the flashy stuff in the front, which makes this interaction all possible, just a significant amount of data means a significant amount of automation that is needed just to be able to make sense of it, store it in the proper sense, and be able to extract information when we need it.

John Gilroy: Awais, you talked about the year in the future, so I'm going to ask you to gaze into the future for me here. So when you gaze into the future, how do you see the collection and use of Earth imagery evolving?

Awais Ahmed: Yeah, so I would say I think just like GPS, GPS three, four decades ago was limited to just a few military organizations around the globe who are using this for the positioning and the navigational systems for the defense intelligence community. But when you look at GPS today, it's become so ubiquitous that everyone uses GPS on a daily basis, whether we're using Google Maps, or whether we're using Apple Maps, whether we are going from point A to point B.

Human life today would almost be unthinkable without GPS. And that's one of the very good examples of how space technology is bringing down the benefits of space down to Earth. And similarly, I think that's where we will see Earth observation going as well. Right now, it's limited to just a few organizations, predominantly governments that are buying this data, that are looking at what is happening.

But as we talked about the queryable Earth, imagine an entire foundational model on all of the satellite imagery and all of the Earth data that's coming in, and anyone can just go on an app and ask it any question you want, and it'll give you real-time information on what's happening.

So I think that's probably what the next 10 to 20 years will bring, Earth observation, making our planet a lot more transparent and a lot more sustainable place where anyone without any technical expertise can just go in and use satellite imagery as one of the sources to obtain any information about the world around us.

John Gilroy: Awais, I think you've given our listeners a great ability to understand and maybe even see invisible problems.

Awais Ahmed: Yes, yes, absolutely.

John Gilroy: I'd like to thank our guest, Awais Ahmed, founder and CEO of Pixxel.

Awais Ahmed: Thank you, John. Thanks for having me.