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Seeing and sensing Australia (and elsewhere) from space

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It's really a privilege to be here speaking about this very briefly today at, as has been observed, a really opportune time.[1] I'm going to take you on a journey about remote sensing looking down.

We've heard about how inspirational it is to look at space. We've heard how inspirational space engineering and enterprise is, yet astronauts who go into space will almost always talk about how moved they are and inspired they are when they look back at Earth from space, when they observe Earth as a sole planet in space, a fragile beautiful place that we live. The image called 'Earth Rise' is famous. It was taken on Christmas Eve, 1968. It's said to be the most important environmental photograph ever taken.

Perhaps that's one of the reasons that many, many satellites have since been launched to observe Earth. We have constellations of satellites in low-Earth orbit capturing data, measuring our atmosphere, our oceans and our lands. That's produced things like images of Australia through programs like the Landsat satellite which celebrates 40 years of cooperation with Australia this year, or this week in fact — the Director of the United States Geological Survey is in Alice Springs.

The efforts are held together through international networks of people and infrastructure, symbolises by this dish in Alice Springs, painted with colours that are of significance to the native American people in the Sioux Falls area of the US. I would love to spend time talking about all the leadership that Australians have done in Earth observation, but not today.

What's really exciting about this area at this point in time? Everybody's heard about remote sensing satellites; but, frankly, the supply chain that links those satellites to decisions has never really matured. By the supply chain, I mean on the one hand we have satellites taking measurements, on the other we have people making decisions. Look at something like positioning satellites: when I get into an Uber, the driver and I are both using a satellite to know where we are; neither of us knows about it or has to know about it. There's nothing equivalent in this land: remote sensing is looking down.

We're starting to understand what that supply chain looks like and it's starting to transform the way in which we're using and will use these satellites and their information. It hasn't happened before because it's more complicated and more difficult to do, but after more than 10 years of effort, we're just getting there now.

The first step is that now these satellites are not science missions anymore, they're synoptic operational missions capturing high science-quality data, run in an ongoing sense by the European Space Agency, the United States Geological Survey and other international space organisations. The

1 This is an edited version of the transcript of Dr Lewis's talk.

data are free: they're unlicensed so they're open licensed, anyone can leverage them, and they're going to continue; that makes a huge difference.

What that does, though, is produce a problem with data; these data are not easy to use. They contain a lot of noise, they have clouds in them, so the next step that's being taken — based on some really leading work from Australia and other countries over the last decade — is that the satellite operators are now starting to produce these data, not as raw images, but as ready-to-use measurements, and this concept of analysis-ready data has emerged and been endorsed through the international community where these satellites are producing primary measurements of the land surface, the reflectance of land surface, its temperature, its roughness. The word "measurement" is really important because it's allowed this community to start moving into a quantitative science field, rather than a qualitative analysis.

That then leaves a huge problem with big data: how do you actually manage all the data that we now have available and ready to use? An Australian innovation, the Open Data Cube, has actually provided the solution to that, so now we're seeing something that Australia made being taken up globally. A satellite sees the earth as a bunch of strips which are continually building up over time. It's not a good way to work with data.

Computers like to work with data in this sort of format, and so the Open Data Cube paradigm — you'll hear about the Data Cube if you talk to anyone in Earth observation pretty much globally now — is that the data are restructured or indexed into something which is geographically regular and stacked as a time series. Every pixel in every image is calibrated, it's flagged according to whether it's a good observation or has a cloud in it, and the time series is used so that one can integrate or differentiate through time — a bit of an inspiration from the astronomical community — and actually extract far more information than has ever been possible before.

This was invented in 2013 when these data were processed in this way to produce the first map of Australian surface water for the National Flood Risk Information Program that was running at that time. The map — which shows areas where there's rarely water in red, they're flood plains, through to areas where there's persistent water, in green and blue — was a world first; nobody had done anything like this before. There's something like 10^14 actual observations going into that particular map.

It's now a continental product which is updated every month as new data come in, with wide ramifications, and underlying that are a series of measurements.

This supply chain is starting to work; it's starting to be filled out. The last part is how that connects with decision makers; not just decision makers in government, but across all sectors, and that's a process of building opportunities that can allow a user community — an *ecosystem* is the emerging word me — an ecosystem of users to engage with the opportunities presented by these continental products that have been produced, a little bit like the weather service produces maps of surface temperature for the day.

It's not just about water — what I'm showing here is a little black square in the middle of the image. For that black square what's being measured from the same satellites, using an algorithm developed in Australia, is how much green vegetation there is, versus how much bare earth or dry vegetation, and that's been tracked through time from the late 1980s through to present, showing a signal, and the signal corresponds to a cropping regime, a wheat crop, and then it changes in the early 2000s through to a more persistent green as they change the crops to almonds, the implications for water use. The important thing is that that analysis can be done everywhere in Australia and every day, and provided to everyone. Geoscience Australia has been funded to maintain that as an operational capability going forward, and that's Geoscience Australia's Digital Earth Australia program.

We now have a really exciting opportunity where this supply chain, as I said, is starting to work. Just what does that mean? Making space for Australia; what does it mean in this context? I think it has a number of implications.

First, government. For government it means there starts to be this regular and available and authoritative evidence base that can inform decisions in the environment in a way that's never been done before. The New South Wales Government produces a map every month, a state of the drought report. It shows for every parish in New South Wales the status of the farm dams, compared to normal, and it's based on an analysis of those satellite data which are automatically generated; it compares how much and how big the surface of the dam is to normal, based on the history, and produces a map, adds it up by parish to make a map across the state.

Second, things which were not anticipated when the satellites were launched are now starting to have real impact. For researchers it's really cool. Researchers in this area traditionally spent 80 per cent of their time wrangling data, correcting data, finding it, getting it, putting it on their computer and correcting it.

I got some feedback from Norm Campbell, who ran Maths and Stats in Perth in the CSIRO when we provided him some ready-to-use calibrated data. He got it straight away. This saved time and let him focus on the research question, "What are the processes that are happening and how are people interacting with those processes?" — the hard questions.

Third, more enthusing: students. We're now at a point where students who are not remote sensing specialists can engage with these data sets and do things that they just couldn't do before. A couple of years ago Emma Johnston, at UNSW, and I got together and created a little collaboration, and Ana Bugnot, her student, produced an assessment of the water quality in all the estuaries around Australia and published it, and someone in the conference that Emma was at took a photo and sent it back to me saying, "Check this out. They're using our data to do this wonderful research." So students can now engage with this and use it as a resource, and they're doing that.

And, fourth, more exciting still, consortia of researchers are starting to use the same data and do things that haven't been done before. There is a methodology for mapping mangroves that's been agreed by a national consortium, and we now have an annual update of the mangroves in this particular part of the coast, which changes through time and expands up till about 2013, and then in some areas of the coast there was a massive dieback as the coastal area contracts to be virtually nothing, all of which can be quantified, but then it can be scaled up so that could be done for the whole country.

So for the first time, having spoken about it for decades, we now have an national assessment of mangroves. Graphs, from the late '80s to the present, show how the total area changes, and how the density of canopy cover changes, so we have national assessments of things which previously were theoretically possible, but completely unaffordable, even if they could agree on the methodologies.

It's interesting to see what this means for industry, which can now engage with these data sources, whereas previously it was too expensive and too difficult. The data may have been free and open, but actually having the expertise and going through the process of getting them, working with them, was an overhead that small-to-medium enterprises, like Spatial Vision, wouldn't contemplate for a normal size product. They could now get these data from Geoscience Australia and leverage them as they see fit.

Other industries are more exciting: a company called Cibo Labs based in Toowoomba uses a map of an agricultural product on an almost daily update by Geoscience Australia which shows how much of the ground is bare earth, how much is green vegetation, and how much is dry vegetation. They take that as an input, then they make it into a pasture biomass map, and add that up by paddocks, and then they feed it to their farmers as an app, as a piece of information that they can use to modify and optimise their land management.

When there was a closure to the US Government on Christmas Eve, 2018, we had a bit of a glitch at our end, because we rely on them. Cibo noticed it straight away and we had somebody fixing it, actually using this in an operational context in the commercial setting. So innovators are getting into these datasets.

I think equally exciting is what it means for these small satellites. We heard earlier about companies putting up tiny satellites. At a conference in California in August 2019 companies like Planet, who make these tiny satellites, were talking about how they're working and what they're doing. They demonstrated that they will use the infrastructure of these highly calibrated government satellites as a baseline, so they will take the weekly satellite observations from the United States Geological Survey, or in this case, from the European Space Agency, and mash their data very accurately, so they can then provide one-metre resolution every day, and they have the authority to correct the data in a way which is consistent with the government science agencies. This is a capability that is relevant to anybody who's using these satellite data.

Most importantly, what does it mean nationally? It means we have billion dollar economies growing on these data. We have a lot at stake here and our primary interests over the last decade or so has been to ensure that these data flows continue. There are at least three ways in which we can do that. We need leadership in international forums, so this week in Canberra there's a Ministerial Forum of the Group on Earth Observations hosted by Australia, multiple international delegations there, and that's a good thing. That's talking about Australia giving back and then helping the community.

I have co-chaired something with Alex Held from CSIRO on the most powerful committee on this Committee on Earth Observing Satellites for a couple of years where we get to talk to people who operate billion dollar budgets, unlike us, with satellites.

We must also look at investing in the upstream section. We have to get something into space so that we've got a real seat at the table with these capabilities. Instruments on satellites that we need and that grow our industry and that are useful to others are the way to do that.

Most important of all, or most impactful of all, is contributing our ideas internationally. We're now taking algorithms, such as the water algorithm we use in Australia, and applying them to whole new continents, such as Africa, as of last weekend. We have taken the software into the Amazon Cloud and now we have the ability to go to Tanzania and look at how water use has changed there. We can expose that to anyone in Africa and they can use it as they see fit and guide its future development.

We're at a really exciting time in Earth observation looking down; not all the inspiration's up. My counterparts in NASA only have $3 billion budgets, but they're still great people to work with when they've got three orders of magnitude more money than you have, you don't have to do much to have some good friends. Thank you.