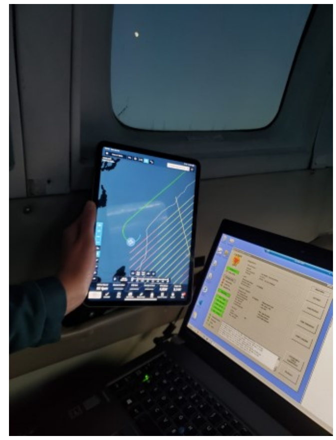
Thank you Marcus and good afternoon everyone.

I've titled my presentation today ADVANCES IN REMOTE SENSING, AERIAL SURVEY AND GEOSPATIAL DATA FOR PLANNING APPLICATIONS and I'm going to provide a brief overview of where we are with most remote sensing technologies including drones, Aerial Photography, Satellite, Thermal, LiDAR and using AI as a tool. I will discuss where they apply, the pro's and con's of each and provide example use cases. Please send through any questions on the chat and I'll try and get through as many as possible at the end.

So to kick off I thought I'd add a little background about myself. I have always loved aeroplanes. When I was at school I spent time hanging out at Virgina airport. Over time, I got to know the crew of an aerial survey aircraft that used to operate there and, occassionally, if I was very lucky, I got to go along for the ride. Over time I learned about operating the camera and eventually started substituting on flights from time to time.

How it started.



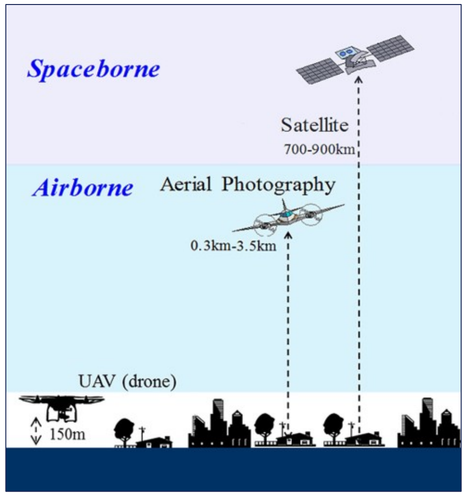
How it's going.

In those days, you had a navigation site that you looked down into in order to see what you were photographing. In addition to making sure that you were taking photo's of what you expected, you also used the nav site to level the camera, set your drifts and overlaps which all needed constant tweaking.

Looking back it had it's moments when you were dripping sweat from the heat and clinging to the nav site with all your might so that your face didn't come crashing down on the eye pice because of the turbulance while at the same time you vomitted into a bag from time to time from looking down in such extreme conditions. But on balance it was an incredible experience and set me on the path to where I am today and of course, things have changed a lot.

Now I have my own aerial survey company and we have offices here in Hillcrest and in Calgary, Canada and hopefully, if all goes according to plan, will be opening in the UK next year. That may sound very grand but we're actually a very small company and cover a specialized niche in the market. We typically don't go for big projects but focus our attention on solving peoples problems. Our clients typically don't know what they want and are looking for a solution as opposed to being able to put out a specification. They only know that they have a need for geospatial information. We typically don't do large contracts and focus on a lot of R&D and often end up learning how to do things ourselves as we do them. Our clients need help and that's what we do. We guide and advise them through the process of solving a problem.

REMOTE SENSING PLATFORMS



There are 3 main platforms for aerial data acquisition. Satellite, traditional airborne and UAV and each has some overlap with the other.

UNMANNED AERIAL VEHICLES (AKA DRONES)

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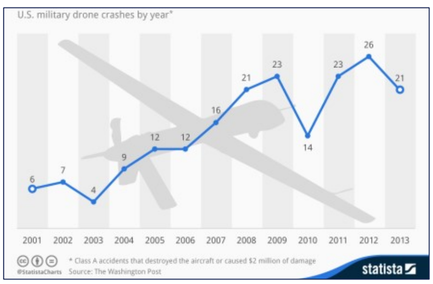
I want to start with briefly covering drones because I don't believe they have much applicability for load planning at the moment but they're all the rage and will be the standard one day so need a mention.

Drones have been a huge dissruptive force in the aerial data acquisition industry and have completely changed how and where we can collect aerial data. They are presenting an incredible opportunity to get a perspective on projects in a way that has never been possible with unprecedented detail. But, as with any new technology there are challenges that will take time to stabalize.

I don't want to get into the ins and outs of UAV's but at this stage drones are currently ideally suited to high resolutions and smaller areas. We are talking about the 1cm to 10cm range and up to a few hundred hectares. That said, drones are being used to complete projects of thousands of hectares but the economics don't really stack up any more. Drone based LiDAR is also starting to become mainstream but also only for very small areas.

WHERE ARE DRONES GOING?

- Sensor payloads are getting smaller and lighter.
- Drones are getting bigger and more capable.
- Range and endurance are increasing.
- Legislation is being formalized.



- Reliability can be improved!

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It is obvious that sensor payloads are getting smaller and lighter and drones are getting bigger and more capable. I think that within the next few years we will continue to see more and more aerial surveys being conducted by UAV.

THE ALTI REACH

- Developed in South Africa
- 6m wingspan
- 10hr endurance.
- 7kg payload.

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As drones become larger and more complex they are going to easily equal the purchase cost of a conventional aircraft. Already it would be no problem to purchase an aerial survey drone for $300-$400,000 dollars and I don't see that cost coming down in the short term.

As an example, this is the ALTI Reach which is being developed locally. It has a 6 meter wingspan and can fly for 10 hours with a 7kg payload

BUT, offsetting the purchase cost is the direct running costs and costs of maintenance which are considerably lower than a conventional aircraft. Add to this the fact that the cost to train a conventional pilot is about a million rand whereas the cost to train a drone pilot is significantly less so your human expense is also less.

All in all, we can expect that drone surveys are going to continue to play a bigger and bigger part in aerial data acquistion but for now, they're not well suited to wide area data collection.

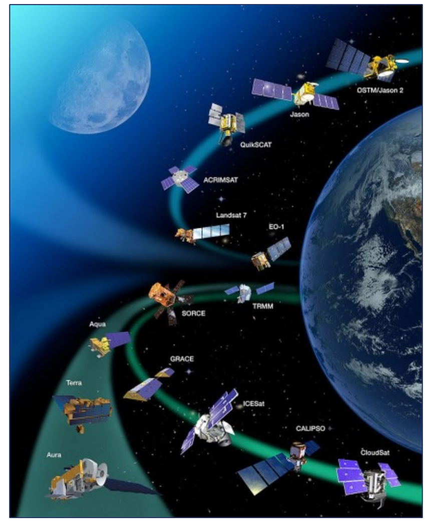
SATELLITE IMAGING

ADVANTAGES:

- A massive temporal archive.
- Available "off the shelf".
- Repeatable, radiometrically calibrated payloads.

DISSADVANTAGES:

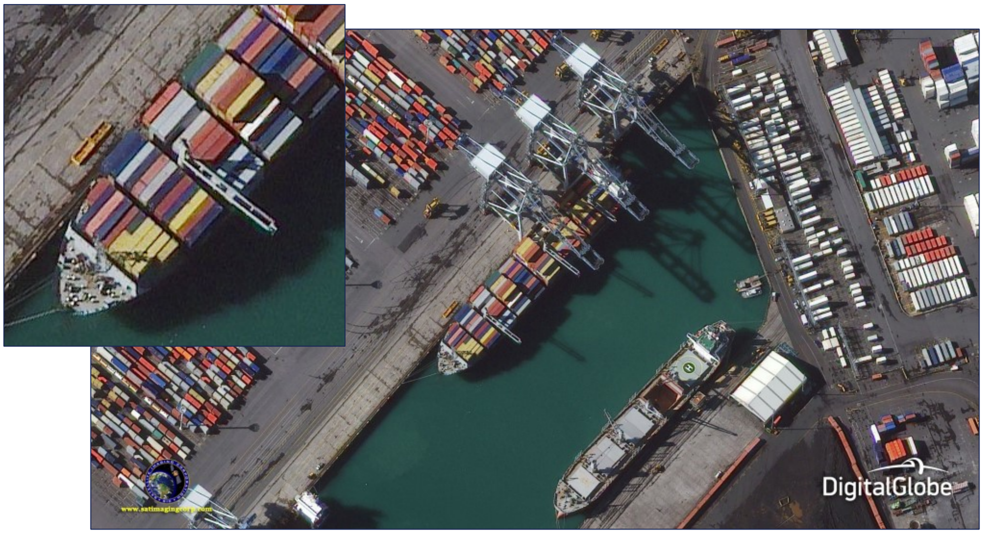
- Resolution.
- Weather and time of day restricted.
- Cost.



So now we get to the first data source which I think is relevant to load planning which is satellite. We frequently get requests for "satellite" imagery but this seems to have become a colloqueal term for any small scale imagery and a lot of traditional aerial photograpy gets called "satellite imagery". In reality satellite imagery is suited to a very specific set of parameters but before we go there, let's just revise a few of the pro's and con's of satellite imagery.

The latest trends in satellite imaging is not so much improvements in the sensors but rather the data becoming more accessible and with this the development of better ways to leverage the data.

HIGH RESOLUTION SATELLITE



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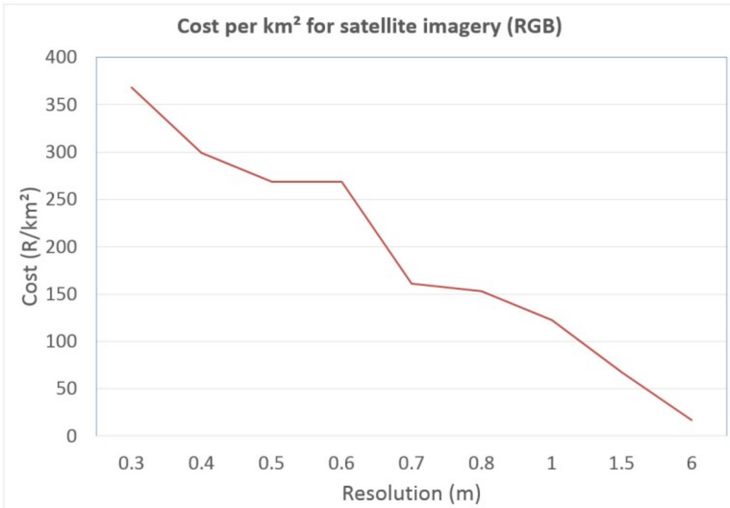
In terms of resolution, satellite continues to improve albeit at a cost. This is an example of what you can typically get from high resolution satellite.

THE COST OF SATELLITE IMAGERY



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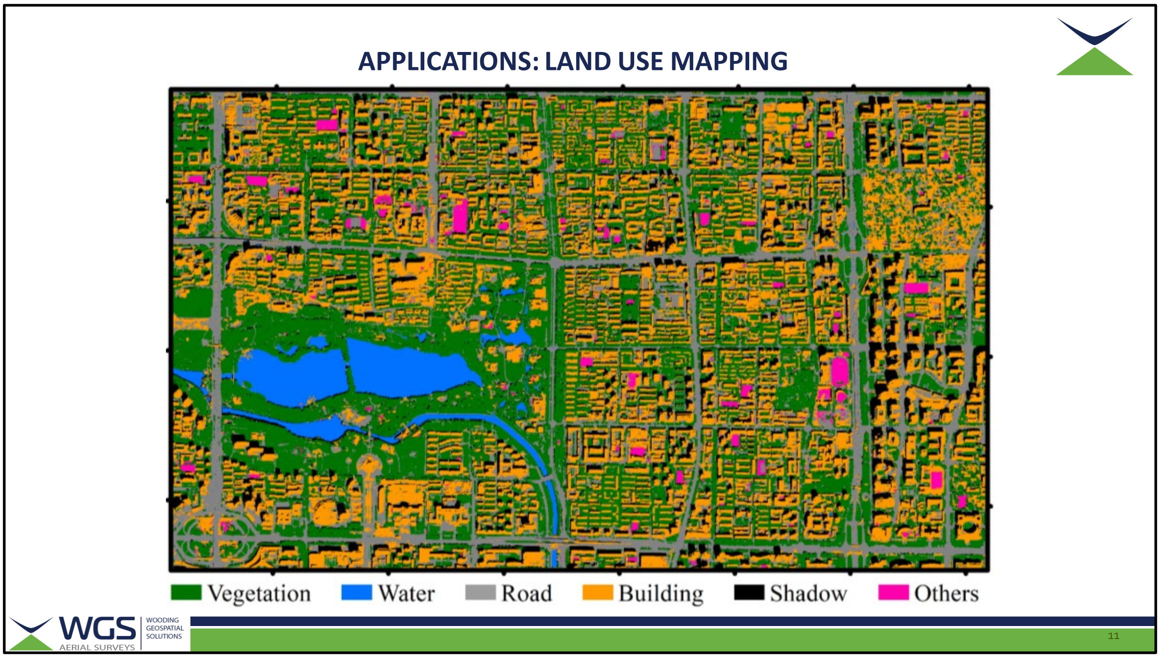
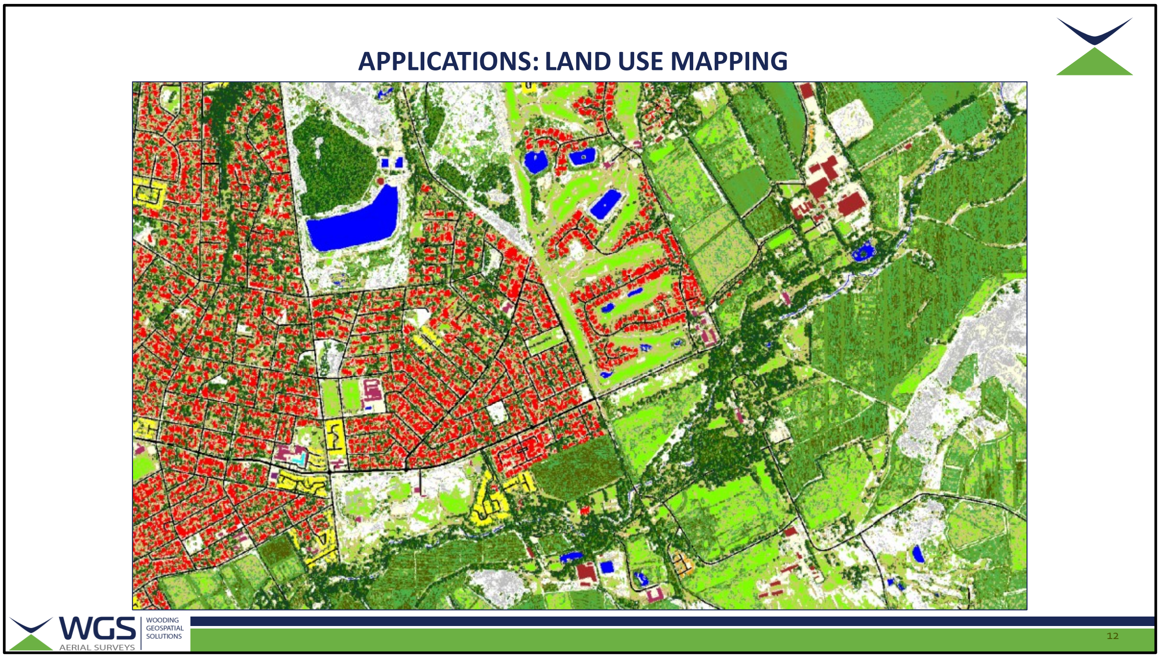
This graph shows the typical cost in Rands per square km for satellite imagery. As you can see, for the higher resolutions, the cost gets expensive and the providers have minimum order sizes. Generally, the opening price for a small piece of high resolution satellite image is R10-R15,000.



The trick is to leverage the advantages of satellite imagery being radiometrically calibrated and repeatedly collected over very large areas. This makes them very well suited for classification which can often be automated.

This is an example of land use mapping over a city which is an entirely automated process.

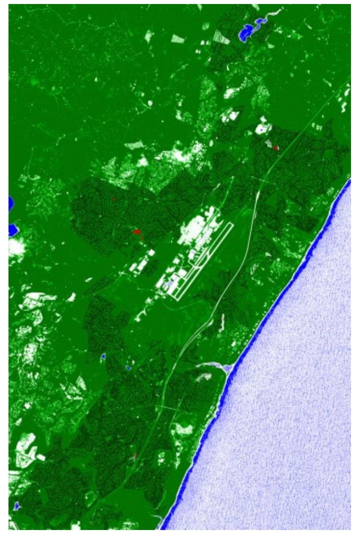


This is a further example from Cape Town. In this instance the classification was done to more classes and from very high resolution imagery.

APPLICATIONS: CHANGE MAPPING

HARVEST TRACKING:

- Free Sentinel 2, 10m imagery
- New acquisition every 2 weeks
- Cost effective solution for many temporal problems.



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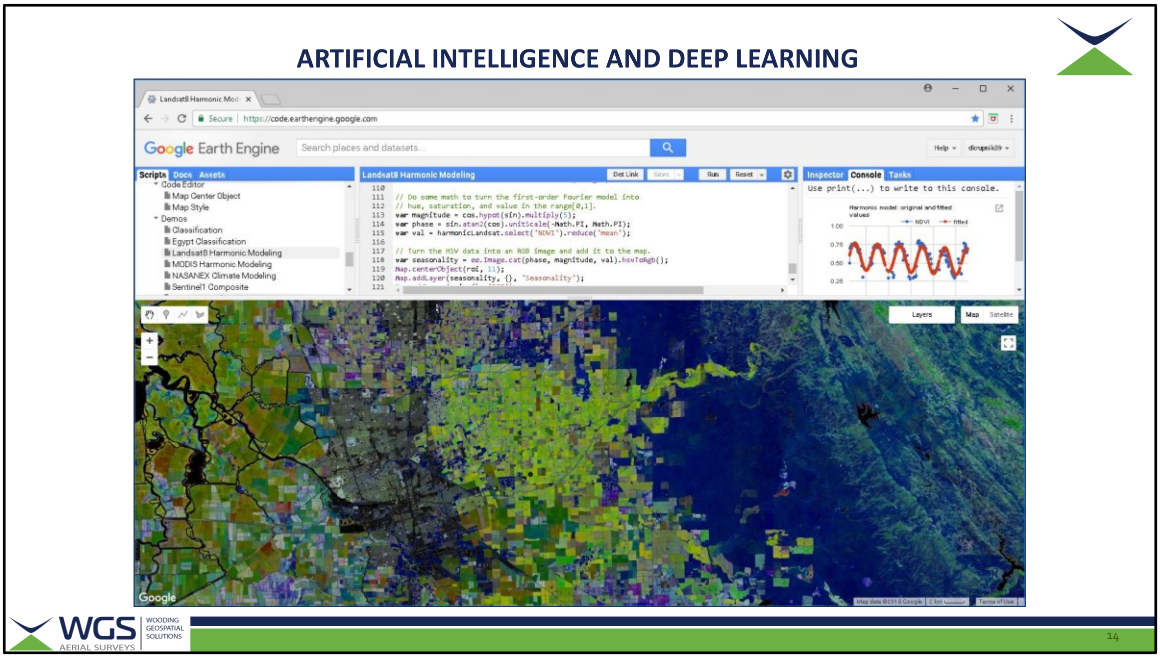
In this example our company was commissioned to find all the areas that were being farmed to sugar cane and then determine the dates that each field was harvested over a year. There is a seasonal window when it is optimal to harvest sugar cane and the mill has to operate at a the right rate to match the crop. The millers don’t have a good handle on how much sugar cane will be harvested in any season to start with and then even less knowledge of how much crop is outstanding at any point in time.

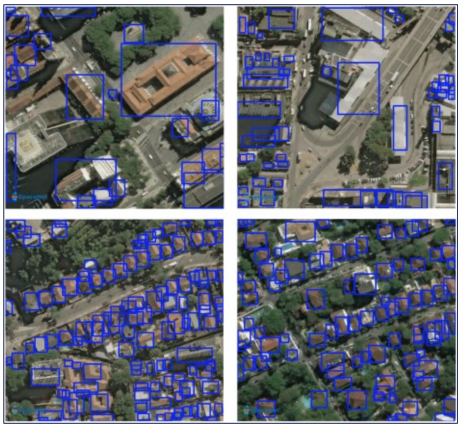
To do this we leveraged free 5 band Sentinel 2 data published by the European Space agency that has a 10m resolution and a repeat rate of approximately 2 weeks so we were able to provide harvest dates to a 2 week period. This type of change analysis can easily and cost effectively be applied to just about any application.



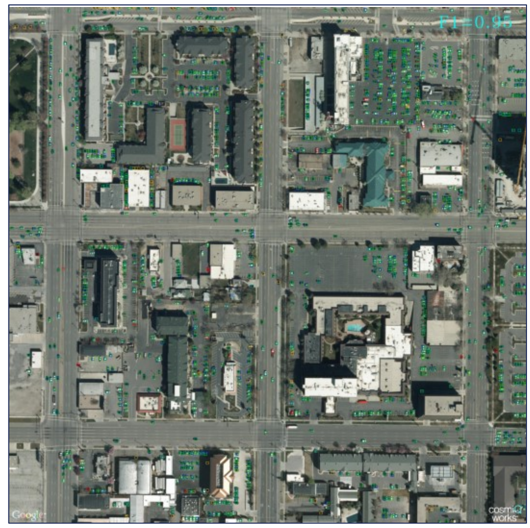
I think that perhaps the area that has seen the greatest leaps in technology is using Artificial Intelligence for satellite image analysis. This is also being used for aerial imagery but because of the availability of satellite data, it is in this field where all the really heavy lifting is being done. These techniques are very different to classical segmentation type approaches. When using AI one typically uses representative chips of imagery which may or may not contain the desired targets as training data. With enough of these chips the model is then able to look for the targets in the unknown dataset. This type of procedure has been successfully applied to everything from counting whales and caribou to cars and buildings.

There are two major AI platforms that have been made available for dealing with remotely sensed data. One is Amazon Sagemaker and the other is Google Earth Engine. Both of these have access to an enormous archive of satellite imagery going back over 40 years. A lot of the data and tools have been made public in the interests of furthering science.

EXAMPLE 1: ENUMERATING BUILDINGS



EXAMPLE 2: ENUMERATING VEHICLES



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Mention Wallmart story.

EXAMPLE 3: COUNTING AIRCRAFT

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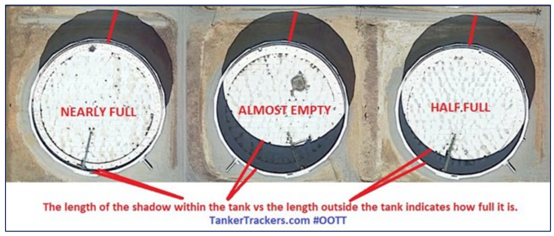
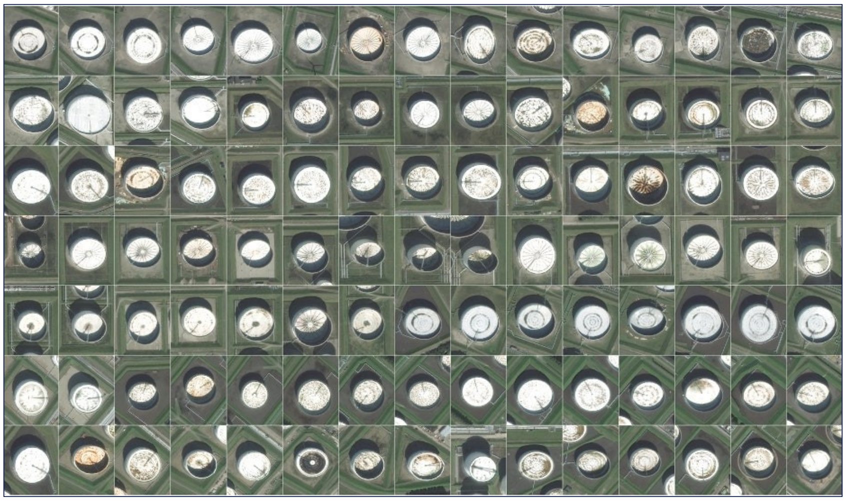
EXAMPLE 4: CRUDE OIL RESERVES





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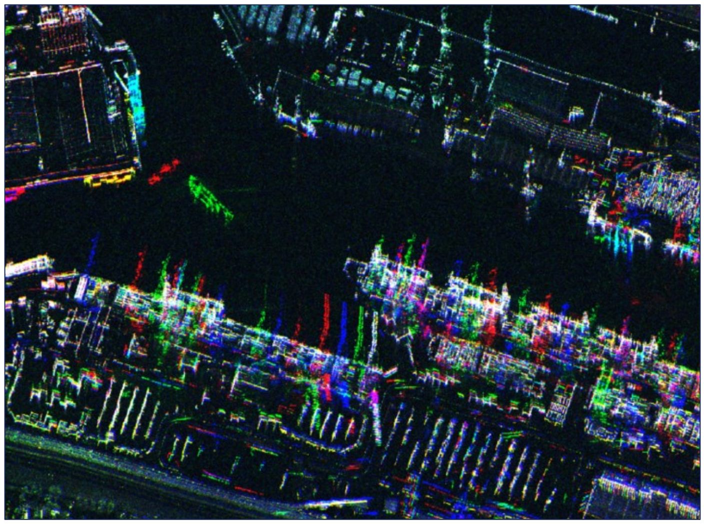
SYNTHETIC APERTURE RADAR

Another new innovation is using Synthetic Aperture. SAR is a so called active sensor that transmits it's own signal so it is independent of weather and time of day. While it doesn't give you a traditional picture by comparing the interference patterns of successive passes over an area it is possible to perform extremely accurate change detection. This is called Interferometry or InSAR and is being used by some mines to measure changes in stockpile volumes. This sometimes leads people to believe that SAR can be used to calculate heights or volumes but that's not true. It is extremely accurate at measuring change though so if a volume or height is already known then a new volume or height can be extrapolated.

SYNTHETIC APERTURE RADAR: HARBOUR MONITORING



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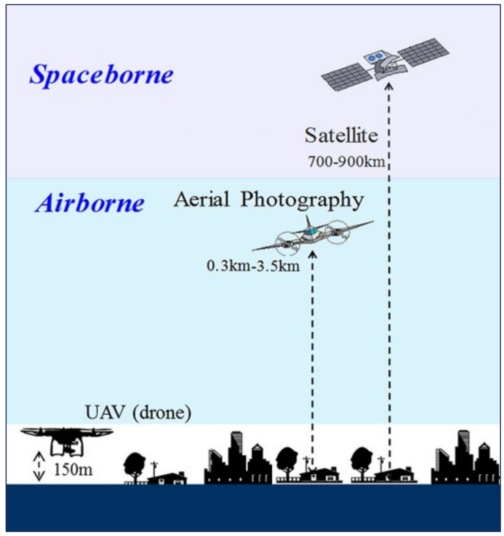
Out of interest, this image is from a new Satellite start-up called Capella Space who are planning on launching 36 SAR satellites to provide a revisit time of 1hr. This image shows the positions of cranes and ships at a port in the Netherlands at 1hr intervals so this kind of development is going to open up an array of new possibilities.

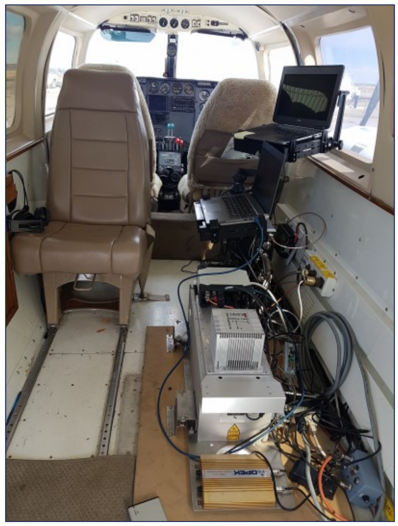
TRADITIONAL AERIAL SURVEY



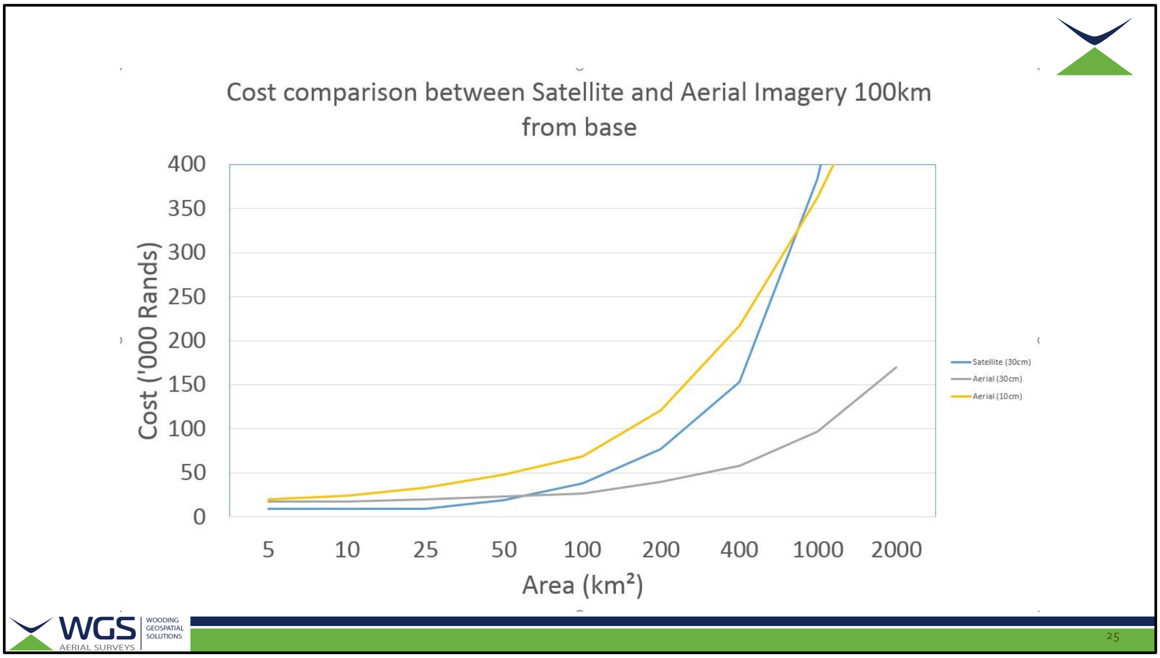
Okay, so now I want to come around to traditional aerial survey. There is no doubt that there is pressure on this segment of the market from all sides. Satellites are getting cheaper and higher resolutions and drones are getting bigger and better and covering larger areas.

None the less, traditional fixed wing aerial survey still occupies a significant segment of the market. If you need large areas acquired at high resoluition or if you need LiDAR then this is still the only way. Drone based LiDAR's are starting to make an entry into the market now but at this stage they are still very limited.

WHY LiDAR STILL NEEDS A FIXED WING AIRCRAFT



This is a picture of our LiDAR equipment as it’s installed. As you can see it is way too hefty for a drone and so we are limited to fixed wing aircraft.

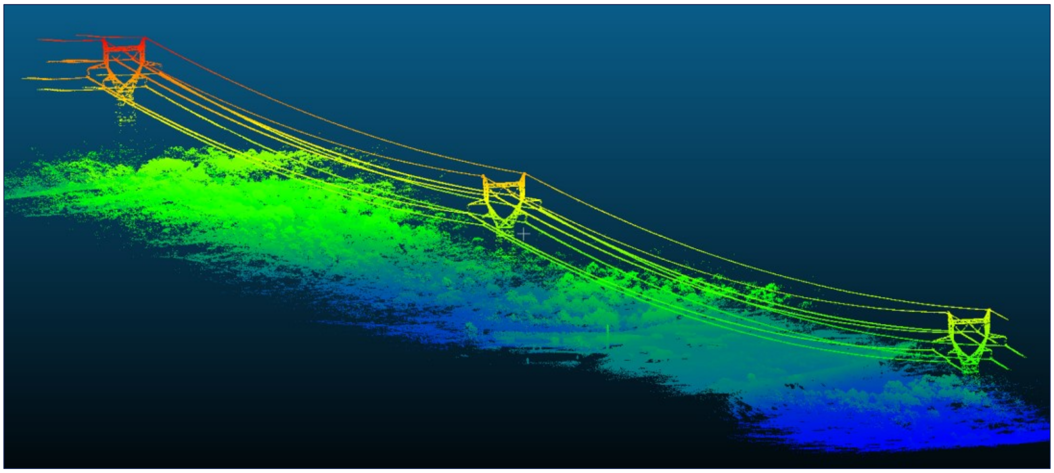


In terms of cost, traditional aerial imagery is generally more cost effective than satellite.

Here is a graph of what it would cost for satellite imagery vs. traditional aerial survey for increasing areas a fixed 100km from Durban. The blue line represents 30cm satellite while the yellow and grey lines are for 30cm and 10cm aerial imagery.

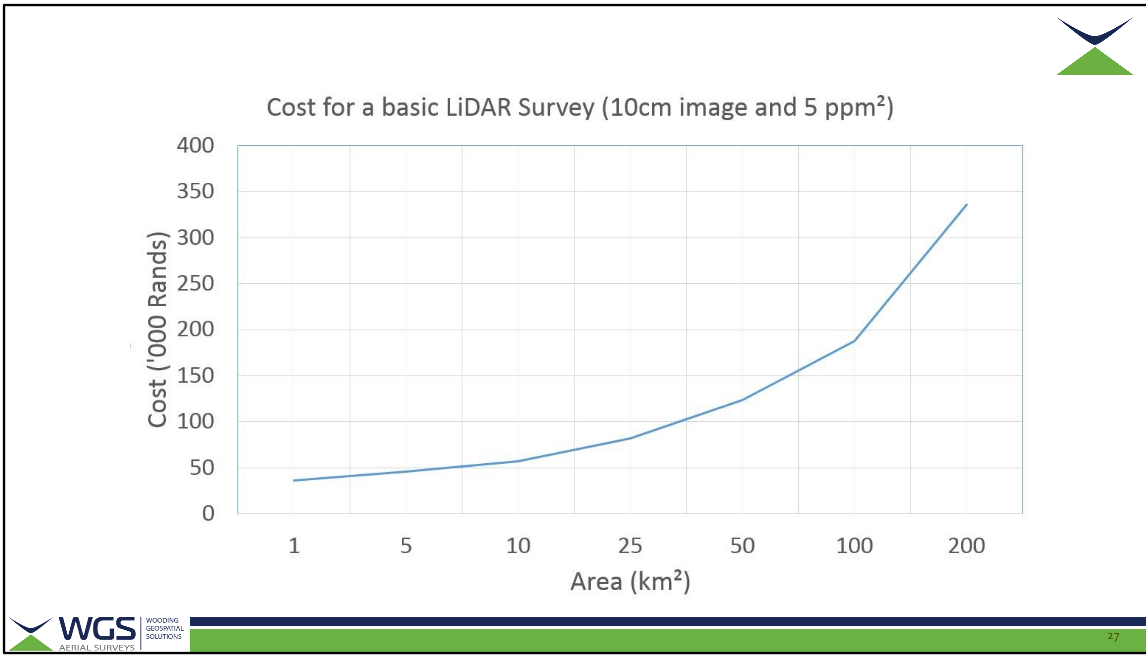
As you can see there is a base cost to getting a fixed wing aircraft into the air. Whether you go for 10cm or 30cm the costs are very similar up to about 15 km² at R20-R30,000. At about 60 km² it is no longer cheaper to use satellite and you would be better off using aerial. And at about 900 km² you could aquire 10cm aerial imagery for the same price as you could buy the equivalent area of satellite imagery.

LiDAR



I would venture to say that LIDAR has not changed all that much over the last 10 years. The sensors have gotten bigger the typical point densities have increased and the costs have come down but fundamentally not much has changed. I think that everyone is familiar with using LiDAR for encroachment analysis on powerlines as well as checking catenary and these tasks can be fully automated.

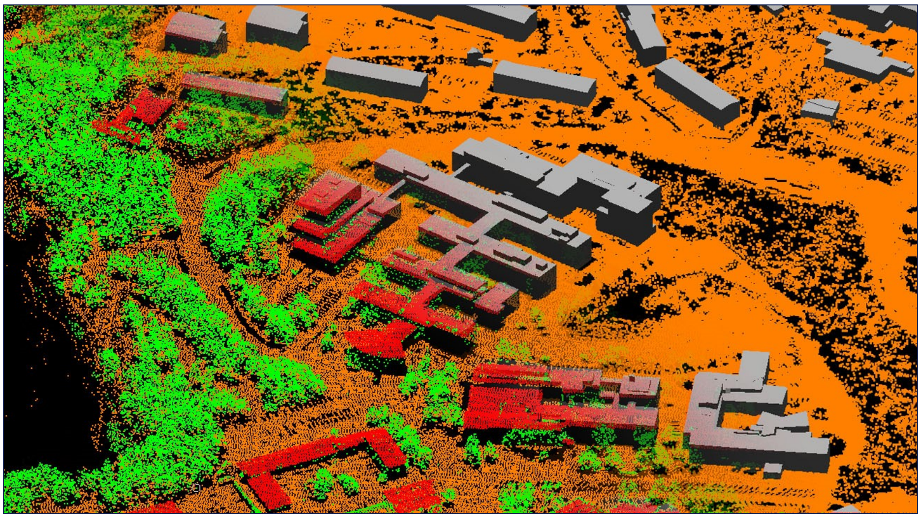
There are new LIDAR type technologies on the horizon now such as Geiger mode or single photo LiDAR which promise unprecenented levels of detail but so far these are still pretty distant.



Just out of interest I have put together graph for LiDAR surveys in order to give an idea of costs but I don't want to dwell on this for too long. Prices normally start at around R35,000 for small sites that are close to base and go up from there. Of course these prices are heavily influenced by accuracy requirements.

Out of interest, there has been a huge demand for LIDAR surveys for wind farm planning over the last few years, many of which we have been fortunate enough to be a part of.

3D BUILDING EXTRACTION



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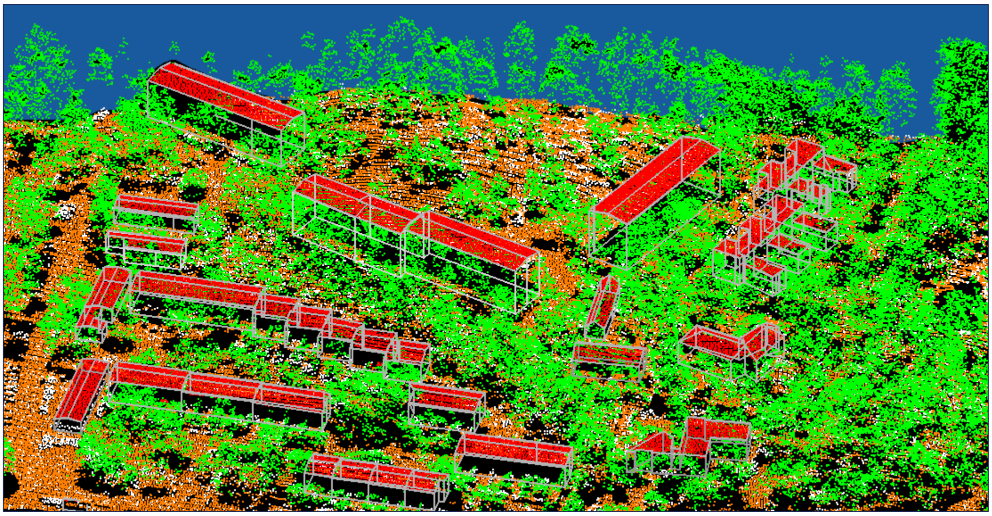
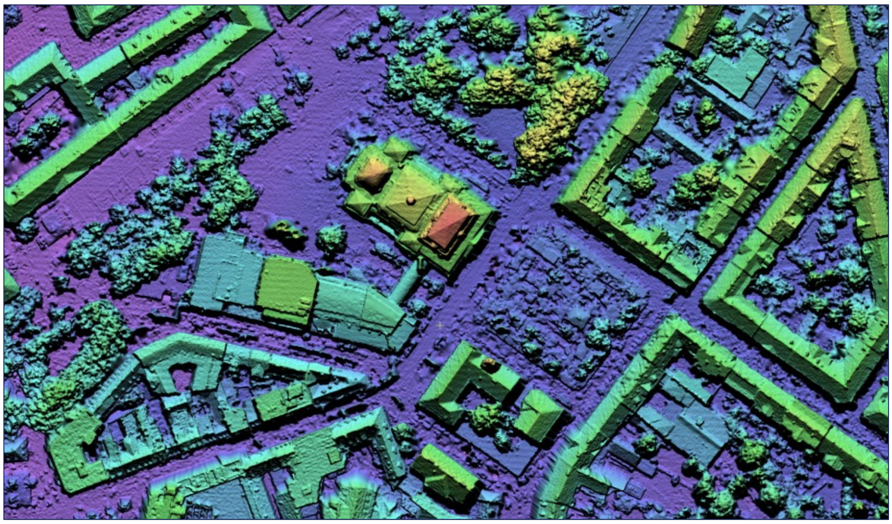
One area which has benefited from the higher point density LiDARS is the 3D modelling of buildings. Basically one can use the LiDAR point cloud to extract wireframes of all the structures in an area. This process is largely automated and is very efficient.

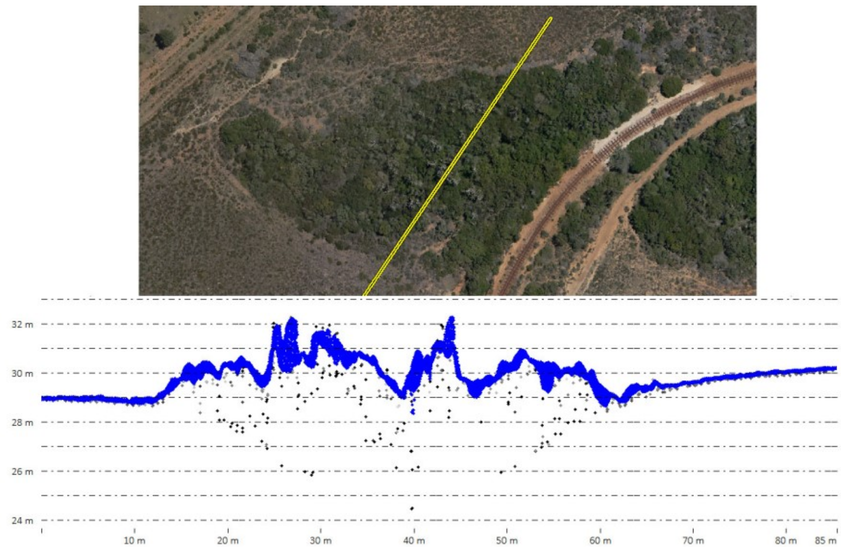


The wireframes have found value in heating and cooling calculations and determining efficiencies for PV installations from the pitch and orientation of roofs. These models are also used for input into digital twins which I will come to shortly.

SEMI-GLOBAL MATCHING



The next area I would like to cover is what is known as semi-global matching or SGM. It is a new technique of matching aerial photographs that leverages the power of GPU processing to creata a point cloud of up to a point per pixel. So, if you, for instance, have an image that has a 10cm pixel size and you use Semi-Global Matching to calculate an elevation value per pixel your point cloud will be 10 x 10 points which = 100 ppm^2! That is an inordinate point density by LiDAR standards where 20 ppm^2 would typically be considered excessively high.



LiDAR is an active sensor it is extremely effective at penetrating vegetation and getting true ground elevations. This is because the LiDAR light shines through the trees and vegetation and a small portion will more often than not get reflected back from the ground.

OBLIQUE IMAGERY AND DIGITAL TWINS

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Semi-global matching is what has enabled the notion of city wide digital twins. Previously it wasn't possible to compute the amount of data required for a digital twin but SGM has changed that.

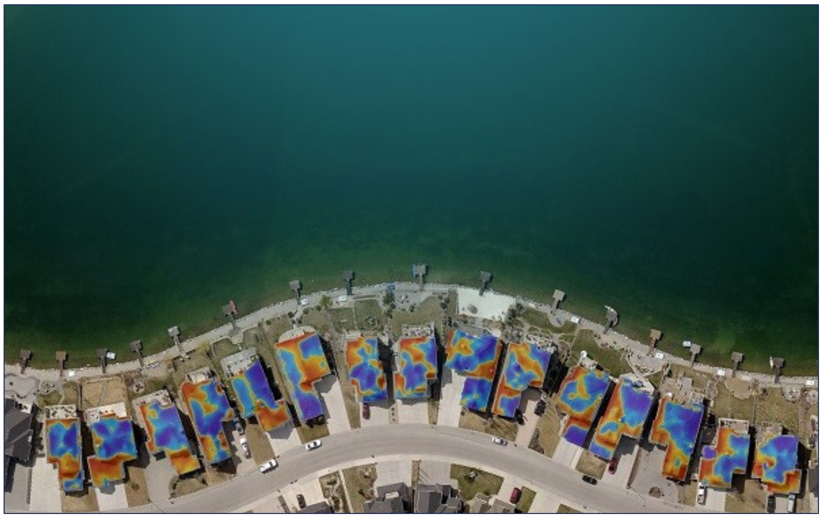
In oblique imaging, 5 high resolution cameras are mounted on a single platform that acquire data simultaneously. Each camera faces in one of the five principle directions being fore, aft, let, right and vertical or NaDIR. This means that one is able to collect imagery of not just the tops of the scene but all angles as well so in a city enviroment this means the facades of all the buildings.

Then, by processing all this data using SGM you can completely reconstruct the scene. Ideally the area needs to be flown with high accuracy LiDAR as well and this is to create the wireframes previously mentioned. This is also often done using SGM processes but the results aren't as good.

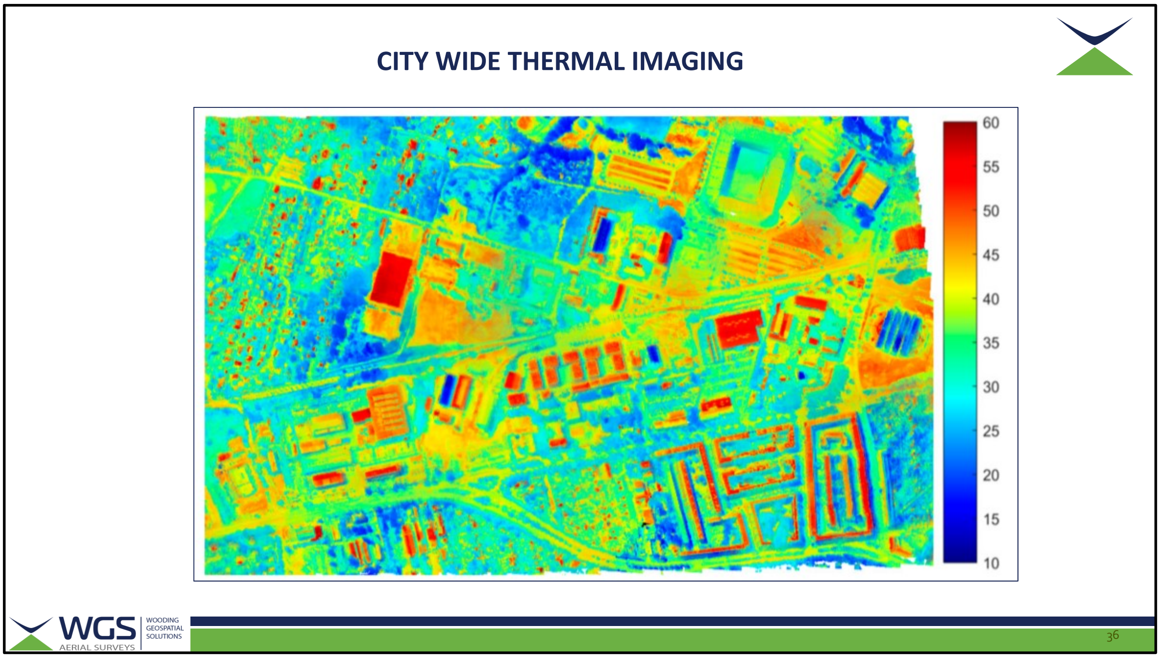
Also, in urban canyons it's not possible to get views of the facades down to street level. In these situations the model is supplemented with imagery from drones or even vehicle mounted cameras at street level.

As you can imagine the cost of creating a digital twin is excessive but they are gaining a lot of attention in first world countries and they are constantly discovering new applications for these.

THERMAL IMAGING

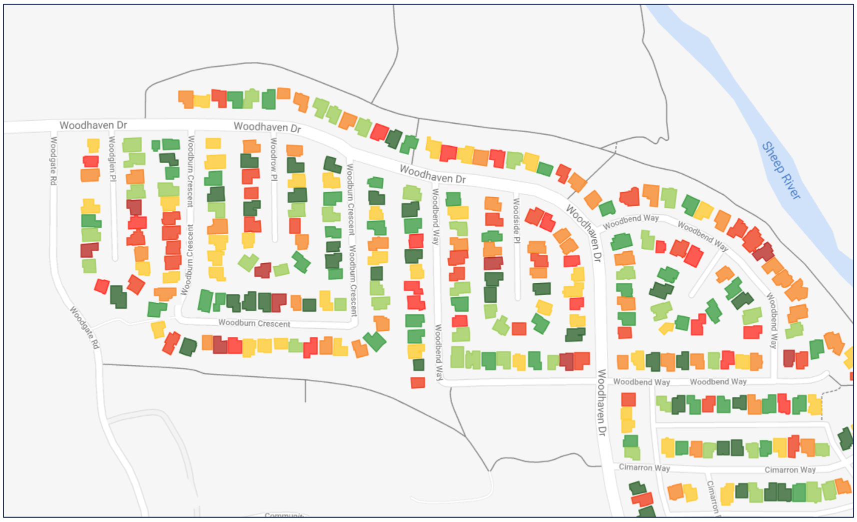


Aerial thermal imaging isn’t really a new technology but the processing has been improving and the sensors are getting bigger very slowly. Thermal cameras are extremely sensitive and able to detect to within .01 of a degree so are well suited to a number of applications. We have conducted a few thermal surveys of coal dumps and quite large areas searching for underground fires.



But from a load planning perspective, thermal imaging of cities has become mainstream. In Canada we have been involved with a company called ITRES who have developed an advanced thermal sensor and have been deploying it to measure the heat loss from buildings. Obviously there is a direct correlation in Canada between how thermally insulated a house is and what the energy demand is.

HOUSES COLORED BY HEAT LOSS



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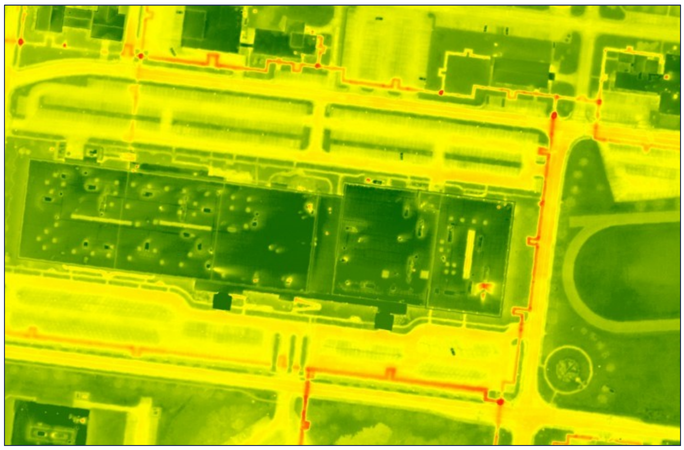
The thermal mage is converted to a simple efficiency index for houses which is made public and gives prospective home buyers the ability to be able to see how thermally insulated a house is and authorities are able to incentivize home owners with older, less insulated homes to upgrade their houses.

And thermal doesn't just need to be used to measure heat but can be used to measure cooling as well. So in Sydney, there used to be a bylaw that high-rise buildings needed to set their airconditioners to ambient at night. A pilot project was conducted where they flew the city with thermal to detect buildings who were ignoring the bylaw. All the buildings that had a blue halo were in trouble!

THERMAL UTILITIES MAPPING



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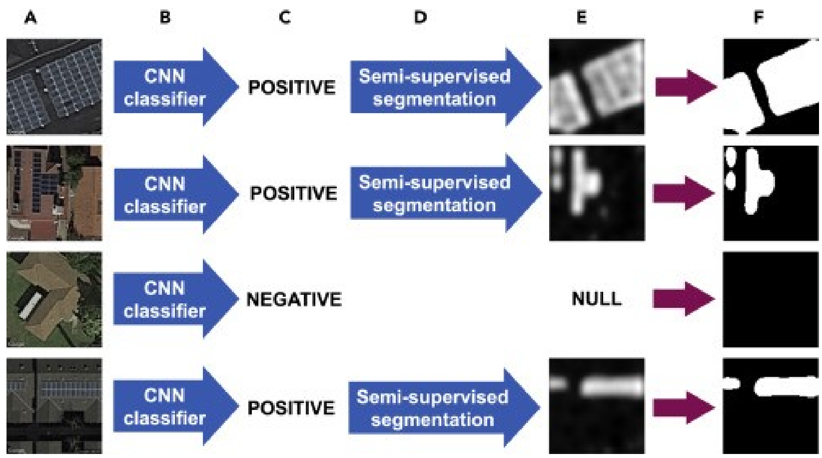
Thermal has also been used for service detection but you need a decent temperature gradient for this so it’s mostly mapping hot pipes in cool climates.

SOLAR PANEL ENUMERATION

A final area that I was specifically requested to talk about was city wide solar panel counting. I'm sure some of you have come across the widely publicized DeepSolar project by Standford University.



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In this study the researchers used A.I. to develope a convolutional neural network which contained both an image classification part and a semantic segementation part to estimate the size of the panels. 370,000 100ft x 100ft chips of imagery from urban 30cm satellite imagery were used as training data and each chip was marked as either positive or negative depending on whether it contained solar panels. So basically this type of model learns based on the characteristics indicating the presence of solar panels, such as color, texture and size.

When the model was tested it was found to be 90% accurate and was ultimately run on 48 states to count 1.47 million solar panel installations.

So, the simple answer is “yes” it can be done. Moreover, the Deepsolar published all their research, algorithms and traning data for people to be able to replicate their research. It would, however, take a little bit of legwork to apply to a

South African context.

- Satellite image quality in the US is is substantially better than what we have available here.
- Most municipalities have aerial imagery that would be adequate but it’s not from a single source and is of different ages and is at different resolutions.
- Our buildings are styled differently to American buildings implying new training data will be required.

AFTER SLIDE:

I was also asked about differentiating between PV and Solar Heating panel types. This would be a challenge and out the gate my only thought would be that heating panels are often stand alone whereas PV panels are almost always in groups so you could do a broad separation based on size but other than that it would be pretty tough.

Thank you very much for your time and I hope that I have provided some content that could be of use or interest. If anyone would like to contact me for more information please feel free to do so.