Eye In The Sky

Could satellite monitoring technology be the future of waste management? CIWM's **Greg Logelain** takes a look at the possibilities and application opportunities this could bring…

Having recently written an article on space waste being a potential issue for the future as an abstract example of producer responsibility (*CIWM Journal*, February 2016), this time I have turned my attention to satellites and the benefits, rather than challenges, they could bring to the waste industry.

When attending the Future of Waste Management & Recycling Conference and Exhibition, run by the University of Salford earlier this year, Jonathan Shears from Telespazio gave a presentation on "Helping you spot the rubbish – from 600km". His presentation provided a brief outline of current space imaging technologies and opened up initial ideas about where this could be applied to waste management practices in the future, as a currently unexploited and unexplored area for improving business efficiency and capability. In his words: "space man meets bin man".

The Technology

TELESPAZIO IS a joint venture between Leonardo and Thales, and is one of the world's leading players in space satellite services. The company, headquartered in Rome, also has offices in the UK and works closely with the UK Space Agency and other government departments, such as the Environment Agency, Cabinet Office and the Ministry of Defence.

Telespazio has preferential access to the COSMO-SkyMed Earth Observation programme, consisting of four radar satellites. It is termed as "high revisit", meaning that they make a minimum of two passes over any fixed point on earth every day. In the UK , however (being nearer to the pole) this increases to eight per day. The satellites have variable imaging modes, one of which has the ability to detect objects of 30m in size over an area of more than 400,000km^2 – useful for detecting and tracking ships in the ocean, for example. Another imaging mode can resolve features as small as just one metre in diameter, such as individual cars, over an area of 100km^2. However, it is the satellites' ability to monitor surface changes of as little as 1-3mm, both day or night, which brings a number of exciting possibilities for waste management.

In short, there are three main processing tools in the satellites' arsenal that can be used from their frequent daily overpasses:

The first is "change detection" or "coherence analysis". As the name implies, this can be used to tell you if an object has moved, appeared or disappeared from one fly-by to the next.

For example, looking at Figure 1, the coloured

Figure 1: detecting ship movement using multi-temporal SAR satellite imagery (Copyright ASI, processed by e-GEOS)

features indicate objects that have either moved away during the imaging period, are currently not present in that location, or have arrived since the surveillance started. In this case the coloured shapes are cargo ships in a port, where the various colours denote presence or absence during specific periods, allowing monitoring of port activity on a twice daily basis and enabling a detailed manifest of container shipments by date. The absence of colour indicates no change, but some of the oil storage tanks do show some movement, meaning re-supply or extraction of oil from them depending on the allocated colour.

In terms of a waste application, at high resolution this type of processing within a landfill site could detect new deposits (potentially of illegal tipping if the site is officially closed); and correct storage at MRFs and transfer stations, such as identifying the correct spacing to reduce the spread of fires. Given the ability of radar imagery to acquire at night (and see through clouds), reliability of imaging is very high. Illegal tipping could therefore be identified day or night, and measured to within an accuracy of around one metre.

The second is "SAR Interferometry" or "surface change" – commonly referred to as "InSAR". This is the mapping of surface deformation, which has already been used to assess structural movement after earthquakes, because of its ability to measure land movement (subsidence or heaving).

InSAR is, however, also used also in civil engineering to detect subtle movements in buildings and roads. As illustrated in Figure 2, on what was the Millennium Dome – now the O2 – it shows areas that have moved, with red tones indicating larger movements up or down and more stable areas are in lighter green tones. In this case, one would expect some movement in the Dome's pylons and smaller movements on road surfaces, but it illustrates how sensitive the InSAR technology is to detecting movements down to precisions of just 3mm.

Its waste application could be to apply it to landfill sites to detect slight movements such as the build-up of gas pockets, natural settlement or sealed bunds to detect slippage or slope failure and hence deliver early warning. On a wider scale, it could be used to measure collection rates by highlighting areas of high compliance and showing where exactly in the site waste is being deposited on a regular basis.

And thirdly, "SAR Radargrammetry" – this processing technique uses a pair of images to measure absolute height and creates digital elevation models (DEMs). When multiple DEMs are compared it is possible to visualise height changes between the two dates; because they are 3D, they can additionally measure volume. This is used in forestry projects to identify gaps in the forest canopy, so as to detect logging (legal or otherwise) or the loss of trees from storm damage.

In much the same way as being used to check illegal tipping or MRF sites, it would be possible to detect if a pile of waste is increasing in height or decreasing; to calculate the volume of waste; and, over a longer surveillance time period, determine the rate of deposition or settlement.

Further Applications

OTHER WAYS satellite technology can help could be the use of basic (ie, optical – think Google Maps...) satellite imaging of waste transfer station fires. When fires spread throughout stores of potentially hazardous waste and become vaporised, optical imagery can "show" the smoke then track fume dispersal on the day and warn those downwind sooner. Frequent imaging would then enable the severity and concentration of the particle cloud to be tracked, the speed of dispersion could be estimated and high risk areas predicted.

Equally, high revisit satellite observation can be applied to geomonitoring, as satellite images ➥

Figure 2: detecting movement at what was the Millennium Dome. (Image courtesy Telespazio, processed by e-GEOS)

are used to monitor all kinds of natural processes and man-made activities, such as coastal erosion, deforestation, melting ice caps, urbanisation, flooding and even traffic flows in cities.

Of recent interest is the impact of flooding on landfill sites. Radar imagery is fantastic at identifying wet from dry and it is currently being used by the Environment Agency to help map flood extents. This can be used to monitor landfill sites in flood risk areas and prevent large-scale run off and avoid major pollution of flood waters, especially hazardous in urban areas. As in Figure 3, the satellite software can be used to depict the water edge boundary in a flood event along a river, near urban areas.

This is a serious consideration, as recently published work by Dr Kate Spencer and James Brand from Queen Mary University of London shows that a possible 1,200 landfill sites are located in coastal areas and estuaries and are at risk of erosion in England and Wales alone. With a further 2,900 additional landfill sites located in flood plains, this makes use of such a tool more and more applicable to such large scale management.

Taking Advantage

TO START taking advantage of this technology now makes sense, but currently we are using it in a different way, using GPS tracking to monitor truck collections and waste movement. So could this be the next step in the evolution of monitoring waste? It just needs adapting to fit around current systems and, indeed, I have listed just a few ideas and potential applications… there may be other uses specific to certain specialised operations too.

As a monitoring method, satellite imaging is non-invasive, with the ability to access difficult to study areas with impunity and ubiquity. In the case of bin compliance, it could allow for large-scale monitoring over entire towns in a very short time scale, which is useful for time-sensitive situations such as the first few hours of a bin collection service. Bin collections would have to be planned to coincide with satellite imaging overpasses (for optical imagery this is usually mid to late morning) and the bins would need to made image identifiable (such as using reflective paint). It could provide a novel bin monitoring solution for the future…

The next consideration is affordability. Whilst the costs of designing, building and launching satellites are astronomical, the costs of using data from them for the minutes of their lifetime that it takes to collect an image is surprisingly low, with a single image costing in the region of £1,000. The processing can be done within 30 minutes of downloading from the satellite, so the information would certainly be "fresh".

The primary costs come from the data itself, rather than the processing, but the UK Space Agency is providing financial support in this area in order to stimulate the use of "space technology" and drive the recognition that it can assist business and enhance the economy. In particular, the CORSAIR data access program provides free access to COSMO-SkyMed products for eligible R&D projects. Jonathan Shears ended his presentation by stating "…space is no longer the final frontier – in fact, for the waste industry, it could be just the beginning".

Currently satellite technology is only just becoming an available commodity and its uses are being seen as ever more valuable and intertwined with the running of most activities. Newer satellites are becoming so plentiful that global coverage (over land and sea, that's 510m sq km!) at three metre resolution (that's the length of a small car) is collected every 24 hours. In the future you won't buy imagery, you will rent it for 24 hours.

So now is the key time for making the most of this opportunity to expand its uses into a similarly expanding industry. Did you know that if you collated all the data that our satellites collect in one year, and put it onto DVDs, it would form a stack almost four times the height of the Empire State Building? So, with a wealth of information above our heads, we should be looking to access this library and bring the information back down to earth… ■

You can contact Jonathan Shears at Jonathan.Shears@telespazio.com. My thanks to him for providing the images and guidance when writing this article.

Greg is the technical advisor for CIWM; working within the technical team to provide waste industry advice for members and non-members, as well as managing a number of Special Interest Groups for the Institution's wide range of topics. He is responsible for the CIWM weekly online newsletter along with coordinating the creation of guidance documents for the sector.

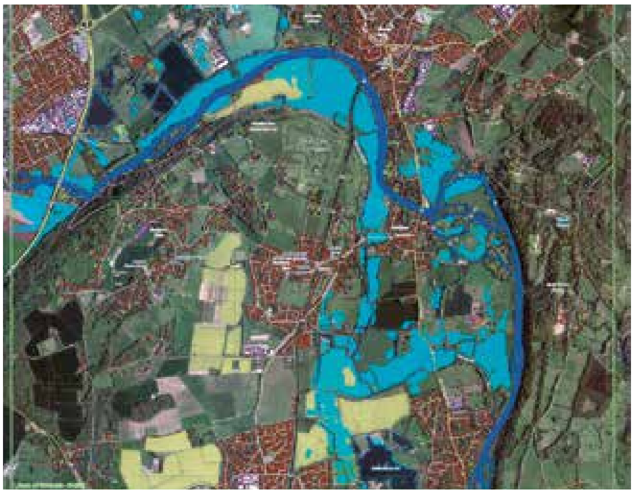

Figure 3: flood water extents extracted from radar imagery [processed by e-GEOS)