Journal of Environmental Law **22**:1 © The Author [2009]. Published by Oxford University Press.

doi:10.1093/jel/eqp027 Advance Access published on 24 August 2009

Using Earth Observation Technologies for Better Regulatory Compliance and Enforcement of Environmental Laws

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Abstract

Weaknesses in conventional mechanisms of implementation and enforcement of environmental laws, coupled with pressures to develop smarter and more resource-efficient regulatory approaches, suggest that there are real opportunities for the greater use of earth observation (EO) technologies as a regulatory compliance tool in environmental law. Technological improvements in the capabilities of satellites and associated EO technologies mean these could become increasingly relevant for those working in the environmental law sector. New high-resolution satellites can now produce pictures of near photographic quality and what we can observe from space is changing dramatically. Using these new technologies for observing and providing evidence of environmental compliance could provide significant opportunities in monitoring and enforcing some types of legislation. This article considers the relevance of these dramatic step-changes in EO technologies to contemporary challenges of effective environmental law enforcement.

Keywords: technology, satellites, monitoring, enforcement, compliance, evidence

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1. Context

Ensuring compliance under contemporary environmental regulation is a matter of increasing concern in the UK and other countries. Environmental regulation has undergone a number of reviews and examinations in the UK in recent years[1]; however, it seems that enforcement officials still face a number of challenges, which hamper their quest for effective and efficient enforcement.[2] This article is not concerned with the necessity or desirability of environmental regulation itself, or of questions of environmental compliance generally. These are issues that have already been dealt with in considerable detail elsewhere in the wider literature on regulation, enforcement and compliance in the environmental sector.[3] Instead, this article uses this wider literature as a backdrop against which to consider the use of earth observation (EO) technologies as a new and innovative regulatory method to achieve better compliance with environmental legislation.

As a result of a number of unprecedented technological advances, the opportunities for using EO technologies, including satellites, for environmental monitoring and enforcement have increased dramatically in recent years. At the same time there has also been a notable increase in mainstream awareness and public access to these technologies, led by Google Earth. Observation using satellites has caught the imagination of a large section of the public, but it has received limited uptake so far in terms of legal compliance strategies.

It should be emphasised that the actual application of EO in terms of environmental compliance is currently more theoretical than applied. Its use in this area has been limited to date,[4] in part, because its development has been technology-led, with a noticeable lack of legal co-operation and input on technology design and applications. There has been a poor level of its use relative to its potential in this area, because those working in

1 For example, in the last decade in the UK, there have been high profile and influential reviews into environmental justice, environmental courts and tribunals and regulatory sanctions. See Report of the Working Group on Access to Environmental Justice, 'Ensuring Access to Environmental Justice in England and Wales' (Working Group on Access to Environmental Justice, 2008); R Macrory, 'Regulatory Justice: Making Sanctions Effective' (Cabinet Office, London 2006); R Macrory and M Woods, 'Regulation and the Role of the Environmental Tribunal' (Faculty of Laws UCL, London 2003); M Grant, 'Environmental Court Project, Final Report' (Department of the Environment, Transport and the Regions, London 2000).

2 C Abbot, *Enforcing Pollution Control Regulation. Strengthening Sanctions and Improving Deterrence* (Hart Publishing, Oxford 2009).

3 For example, for an excellent overview on environmental regulation, see C Hilson, *Regulating Pollution: A UK and EC Perspective* (Hart Publishing, Oxford 2000); for an outstanding collection of studies on environmental compliance see D Zaelke, D Kaniaru and E Kružiková, *Making Law Work: Environmental Compliance and Sustainable Development, Volumes 1 and 2* (Cameron May, London 2005).

4 It is already being used in a limited way by regulators in the agricultural and fisheries sectors, but has attracted little interest elsewhere within the environmental law sector.

the environmental law sector have had little or no awareness of what these new EO technologies can do. Before they can be utilised in an environmental compliance context, better understanding and communication is needed regarding whether they can achieve desired enforcement and monitoring outcomes. This article demonstrates how EO technologies are already being used in a compliance context and considers under what circumstances they might be used in the future to monitor and enforce environmental regulation.

2. Technological Step-Changes

Although the use of EO in an environmental law context is still in its infancy, its significance is increasing because of unprecedented advances in the technology. Most significantly, there has been a major technology leap in the spatial resolution capabilities of satellites. Satellite sensors record information at a range of resolutions, the sizes of which are important as they determine the amount of information that can be seen. Until very recently satellites operated at such low spatial resolution that they could only observe large land-use changes. Table 1 shows that in the 1980s and 1990s most satellites operated at resolution levels of about 30–79 metres. Resolution of this size had little value in providing legal information. Since 2000, there has been a major step-change and the most recent satellites have resolution capabilities as high as 0.3 metres.

Far more detailed information can be seen from satellites operating at higher spatial resolutions and the most recent satellites can produce pictures with at least 33 times more visibility than a decade earlier. We can now observe objects from space that are larger than 0.3 metres, meaning that it is now possible to see individual buildings, ships and even cars. Humans can also now be seen on a satellite image, although these technologies are not yet so advanced as to be able to identify them. Satellites are, therefore, now potentially more useful to those working in an environmental compliance context.

Table 1. Significant step-changes in satellite resolution

Date	Resolution (metres)
1970s	79
1980s	30
1990s	10
2000	1
2001	0.6
2007	0.41
2009	0.3

One can assume that if objects so small can be seen then so could certain significant discharge points; for example, a large pipe at an industrial facility or maybe traces of a plume from a pipe. Looking further into the future, the resolution on the next generation of satellites could continue to improve, being as high as a few centimetres, enabling even greater monitoring opportunities.

A further significant development has been that the numbers of satellites are increasing. There are currently many satellites, each with different types of sensors, already in orbit, and many more launches are planned in the public and private sector. It is estimated that approximately 240 satellites with an EO mission will be operational over the next 15 years,[5] providing further monitoring opportunities.

An increase in numbers of operational satellites means that there is greater access to more timely, accurate and cost-effective data. The cost of satellite imagery has been, and will probably remain, one of the most prohibitive factors to its use in a legal context. Costs depend on the provider the data comes from, resolution size, and what level of processing the buyer requests for the data product. Data cost has, however, generally decreased in recent years, particularly for archived data,[6] making it a more affordable option for those wishing to use it. Whilst some high-resolution imagery can still be expensive, the actual cost must be considered against monitoring needs and its value to the user. In some circumstances, it might provide evidence that is not available by other means, or result in financial savings in the long-term when compared to other forms of ground-based monitoring and inspections.

Alongside the large commercial satellites, we are also seeing the emergence of new nano-/micro-/minisatellites, which could either operate in tandem or, eventually, replace the larger fixed configuration satellites. Some of these nano-/micro-/minisatellites have mission costs starting as low as $5 million, as compared to more conventional commercial satellite missions that can have mission costs in excess of $500 million.[7] Such next-generation satellites will increasingly be built 'fit-for-purpose' and could, for example, have specific environmental monitoring capabilities. Satellites are already beginning to be developed to monitor specific atmospheric pollutants, such as NASA's Orbiting Carbon Observatory satellite, which cost $278 million to develop and launch.[8]

5 'Optimizing the Benefits of EO Through International Cooperation' *SatMagazine* (Sonoma, May 2009) <http://www.satmagazine.com/cgi-bin/display.article.cgi?number=1285311106> accessed 26 May 2009.

6 The potential utility of archived data for monitoring will be tackled later in this article—eg Sections 3.2, 3.3 and 4.4.

7 M Sweeting, 'Micro/Nano Satellites – A Brave New World' *Guardian* (London, 10 October 2001) <http://www.guardian.co.uk/education/2001/oct/10/highereducation.engineeringgeneral> accessed 26 May 2009.

8 J Amos, 'Nasa Set to Launch CO2 Hunter' (BBC News Website, 18 December 2008) <http://news.bbc.co.uk/1/hi/sci/tech/7769619.stm> accessed 26 May 2009.

Clearly, other specific environmental monitoring functions could be developed on satellites if there is a need for them.

In the future, there might also be opportunities for individual regulatory bodies to have their own satellite. Sweeting has likened developments in this area to the way that the personal computer has brought computing out of the domain of research institutes and into the office and home.[9] Although we are still at an early stage of such a technological revolution, these nano-/micro-/minisatellites will become increasingly accessible, making them a more affordable and attractive monitoring option to regulatory agencies.

A further EO technology that could be relevant to environmental compliance in the future is unmanned aerial vehicles (UAVs). These can monitor activities on the ground from an altitude higher than that of an aeroplane taking aerial photographs, but lower than that of a satellite.[10] At a development cost of approximately £15,000 upwards,[11] they can be a cheaper option than low-orbit satellites. They are also more flexible and responsive than satellites in monitoring smaller sites and can send even higher quality resolution images back in near real-time to ground stations. At the current time, UAVs are mainly being used for military reconnaissance, but their potential for other aspects of legal control has been already recognised by some police forces.[12] Their potential for coastal and environmental monitoring has also been recognised,[13] but actual applications are mainly at an early planning stage.

3. Environmental Enforcement Uses

In terms of using EO technologies as an environmental compliance tool, the key factor is whether they can offer anything different, supplementary, superior or more cost-effective than what we have under current enforcement approaches. There is a strong argument that they could sometimes have advantages over existing approaches. There is a broad range of opportunities that EO technologies offer and three specific uses in particular can be highlighted. The first of these is that they can be utilised by regulators as part of a targeted enforcement strategy to monitor specific laws. A second example where they might have a strong compliance value is monitoring individual sites or areas where environmental offences have been known to occur

9 Sweeting (n 7).
10 UAVs generally operate in the skies at around 250–60,000 feet.
11 P Bowes, 'High Hopes for Drone in LA Skies' (BBC News Website, 6 June 2006) <http://news.bbc.co.uk/1/hi/world/americas/5051142.stm> accessed 26 May 2009.
12 Ibid.
13 J Twist, 'Eternal Planes to Watch over Us' (BBC News Website, 2 August 2005) <http://news.bbc.co.uk/1/hi/sci/tech/4721091.stm> accessed 26 May 2009.

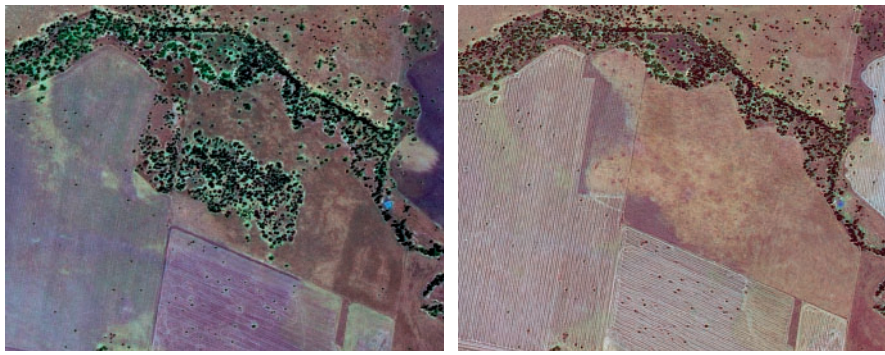

Figure 1. Low-resolution imagery showing 'before and after' clearing (Copyright: CNES©Distribution Spot Image). *Source:* Images were kindly provided to me by the New South Wales Government on 12 September 2007. I am also grateful to Spot Image for allowing me to use these images in this article.

historically. A third use for EO technologies is their use as a form of historical evidence. Each of these areas is elaborated upon in the following sections.[14]

3.1 Targeted Enforcement Strategies

EO technologies have already been used systematically to monitor legislation as part of a targeted enforcement strategy. The core example of using EO data in this way is from Australia, where it has been used in an attempt to curb illegal deforestation associated with farming activities. In the last decade, Australian States have incorporated satellite surveillance of tree clearing within the policing strategies of their relevant legislation. This appears to be the only sustained international example where satellites have been used to monitor and enforce an environmental law in this way.[15]

Figure 1 shows two separate low-resolution satellite images that were used by a State enforcement agency to show illegal vegetation clearance in Australia.[16] There are clearly a large number of trees in the middle of the image on the left. The image on the right, which was taken at a later date,

14 To test the value of EO technology, archived satellite imagery was obtained which corresponded to actual prosecutions that had already taken place, providing the basis for original analysis of whether satellite data could be used to detect breaches of environmental laws.

15 There are of course other examples of satellites being used to monitor laws, but in the environmental sector these are ad hoc and few and far between. The Australian vegetation clearance example is the only sustained example which I have come across in my research.

16 The images in Figure 1 were given to me by the Department of Environment and Climate Change, New South Wales Government, as an excellent example of what low resolution imagery is capable of, in terms of providing evidence. Imagery of this type has already been used in over a dozen prosecutions and many have been used as evidence in court. Statement by Gordon J Plath, New South Wales Government (Personal email correspondence, 23 July 2009).

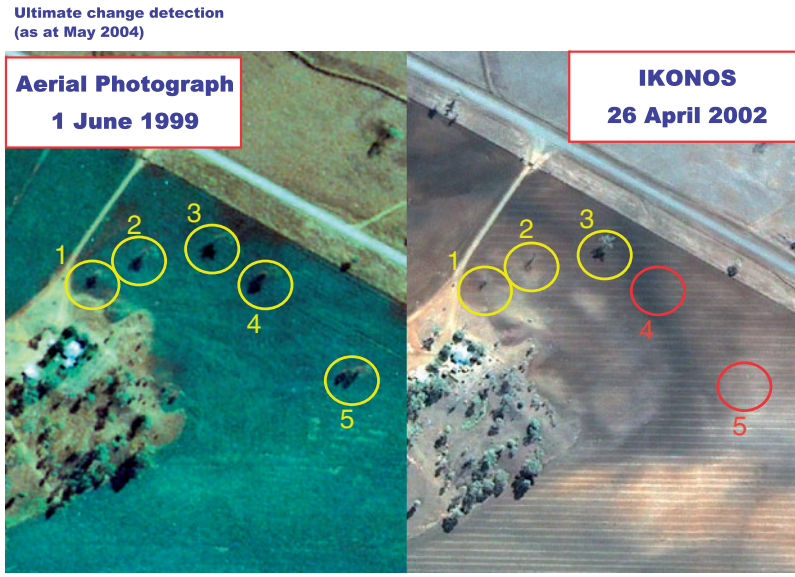

Figure 2. Aerial photograph and high-resolution image showing 'before and after' clearing (kindly provided by the Queensland Government on 6th March 2007. Copyright: [left] Queensland State Remotely Sensed Image Library [right] GeoEye Inc. Copyright 2009. I am also grateful to GeoEye Inc. for allowing to use the satellite image in this article. All rights reserved).

reveals that these trees were removed, without as it turned out, legal permission.

Figure 2 shows two more images that provide a further example of where EO has been used to demonstrate illegal vegetation clearance in Australia. The image on the left, which is from an aerial photograph, shows five individual trees in the marked circles that were present on the land in 1999. The image on the right, taken from a high-resolution satellite image in 2001,[17] shows that two of the original five trees (circled 4 and 5) are now clearly missing. These images show that the trees were removed illegally.[18] Comparison of the imagery in Figure 2 to that in Figure 1 also demonstrates the resolution advances in the technology.

Satellite monitoring programmes, as demonstrated in the images above, allow the rates and extent of land clearance to be measured and compared between areas over time. In Australia, this is often the only feasible way to

17 From the IKONOS satellite, which has resolution capabilities of between 1 and 4 metres.

18 The images in Figure 2 were not actually used in a prosecution, but they are of a property where a successful prosecution for unlawful clearing resulted. They were given to me by the Department of Environment and Resource Management, Queensland Government, as an excellent example of what high resolution imagery is capable of, in terms of providing evidence.

get land cover information for large areas and remote locations over time.[19] Instead of sending inspectors out in the first instance to look at parcels of land, enforcement bodies can use satellites to alert them to any suspicious behaviour that is taking place, before conducting ground inspections. Australia has seen numerous court prosecutions and other forms of administrative sanctions where EO data has been used to demonstrate vegetation clearance. An official in Queensland's Department of Natural Resources commented that 'without satellite imagery to target potentially unlawful clearing and use as evidence there would be little if any vegetation compliance in Queensland'.[20]

A similar form of targeted regulatory monitoring also exists in the agriculture sector in the European Union (EU), where legislation gives Member States the option of using satellites to monitor farm subsidy payments under agricultural cross compliance schemes.[21] Almost all EU countries now use this technology, which can identify crops, determine correct areas of agricultural parcels, and check if claimants are complying with certain environmental conditions attached to subsidies. Satellite images have been directly used as evidence in courts in some EU countries,[22] including the UK,[23] although they are most often used to provide advance notification to the authorities of potential fraud. The US Government has also used satellites to monitor field crop data,[24] and there are examples where it has been used as evidence in court to show false insurance claims.[25] Satellite technologies are useful to regulatory bodies in the agricultural sector in that they allow large areas of agricultural land to be monitored, sometimes with significant public savings.[26]

19 R Bartel, 'Satellite Imagery and Land Clearance Legislation: A Picture of Regulatory Efficacy?' (2004) 9 AJNRLP 1.

20 Statement by Bruce Goulevitch, Queensland Government (Personal email correspondence, 8 June 2006).

21 Commission Regulation (EC) 796/2004 of 21 April 2004 laying down detailed rules for the implementation of cross-compliance, modulation and the integrated administration and control system provided for in Council Regulation (EC) No. 1782/2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers [2004] OJ L141.

22 European Commission, 'APERTURE Final Report' (2000) ENV4-CT97-437 <http://www.ucl.ac.uk/laws/environment/satellites/docs/reportAPERTURE.pdf> accessed 26 May 2009.

23 National Audit Office, Report by the Comptroller and Auditor General, 'Agricultural Fraud: The Case of Joseph Bowden' (2001–2002) HC 615.

24 Statement of Steve Young, US Environmental Protection Agency (Personal email correspondence, 10 February 2006). See also, L Rocchio, 'Saving Millions in Government Dollars: Landsat Helps Fight Crop Insurance Fraud' (NASA Website, 6 April 2006) <http://landsat.gsfc.nasa.gov/news/news-archive/soc.0002.html> accessed 26 May 2009. The US Department of Agriculture (USDA) helps farmers manage their risks through the Federal Crop Insurance Program. Satellite imagery is typically employed if a USDA field investigator determines that claim verification is warranted. The image investigation is performed either internally by the USDA's Risk Management Agency (RMA) or contracted out to a private remote sensing expert.

25 Rocchio, Ibid.

26 Ibid.

Member States of the EU also use satellite-based monitoring systems for inspection and enforcement of fisheries under Community legislation.[27] All EU fishing vessels that operate over a certain size must install a satellite-based vessel-monitoring system to allow Member States to track movement of vessels, to check that they are fishing in authorised areas and to monitor fish catches.[28] The USA has similar satellite systems in place to identify vessels involved in illegal fishing.[29] This form of satellite monitoring is different from the other examples above, as it relies on GPS positional tracking to alert the monitoring agencies of the actual location of the vessel. Again, this type of surveillance can sometimes be cheaper and more effective than surveying entire regions of water with boats or by plane.

3.2 Monitoring High-Risk Offenders

The use of EO technologies could be relevant to current debates on risk-based regulation that are taking place in the UK and other countries. Sometimes, those committing environmental offences will not change their behaviour even if caught and fined. Regulators could, therefore, consider using EO technologies, under certain conditions, to monitor legal compliance after a successful prosecution or to monitor 'high-risk' sites. Figure 3 contains imagery that demonstrates how this might work.

In a case in the UK, in 2005, a defendant was found guilty of keeping approximately 50 scrap vehicles in an illegal scrap-yard without a waste management licence. The offence was originally discovered by the Environment Agency of England and Wales (hereafter, Environment Agency) following a ground inspection. The offence above occurred between June 2004 and September 2005 and the offender was given a set-period of time in which to comply with a court order to remove the illegal vehicles from the scrap-yard. Satellite images in Figure 3, dated May and June 2005, show that there were scrap cars stored on the site during the time of the offence. If this method of monitoring had been used in the first place, then cross-referencing with records on waste management licensing might have alerted the Agency as to whether an offence was taking place.

Of greater interest in the compliance context is the satellite image taken of the site on February 2006, after the date for compliance with the court order. This image, on the bottom right of Figure 3, shows that the vehicles appear not to have been removed from the site and that the court order might not

27 Council Regulation (EC) 2371/2002 of 20 December 2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy [2002] OJ L358.

28 Council Regulation (EC) 2244/2003 of 18 December 2003 laying down detailed provisions regarding satellite-based Vehicle Monitoring Systems [2003] OJ L333.

29 S Hatch-Hodge, 'Satellite Data and Environmental Law: Technology Ripe for Litigation Application' (1997) 14 PACE Envtl L Rev 703.

Figure 3. High-resolution imagery monitoring 'high-risk' offenders (Copyright: DigitalGlobe). *Source:* Images kindly provided to me by DigitalGlobe on 5 June 2007. I am grateful to DigitalGlobe for allowing me to use these satellite images in this article.

have been complied with. A closer examination of the image also reveals that the illegal activity might have actually intensified, as it appears there are more cars on the site. Although they were not actually used by the authorities in this case, EO technologies might, therefore, under certain conditions, be used by regulators to check legal compliance as part of a risk-based enforcement strategy. This could include monitoring sites with a high-risk of offending or a defendant's performance after a successful prosecution; for example, checking on any subsequent clean-up operation.

3.3 Historical Evidence

The greatest potential enforcement use for EO technologies is to provide historical evidence. Systematic archiving of satellite images could in theory provide regulators or a court with a relatively impartial snapshot of any location at any given time, providing accurate evidence that would often be otherwise unavailable. Figure 4 contains imagery illustrating how historical evidence from satellites might work in an environmental compliance context.

In 2006, there was a prosecution in the UK for an offence relating to an illegal landfill site. This was a major criminal operation and the rubbish that was burnt caused a mound of ash that was 3 metres thick and measured 260 metres in circumference. It was calculated that by burning wastes and

Figure 4. High-resolution imagery demonstrating historical evidence (Copyright: DigitalGlobe). *Source:* Images kindly provided to me by DigitalGlobe on 5 June 2007. I am grateful to DigitalGlobe for allowing me to use these satellite images in this article.

hazardous wastes to this extent, the offender would have received an annual turnover of approximately £40,000. At trial, the Environment Agency stated that this offence took place between May 2005 and January 2006. The two images at the top of Figure 4,[30] dated October 2005, appear to show, in the circled area, the burning of waste on this land during the already known time of the offence.

The two images at the bottom of Figure 4, dated June 2004, were taken nearly a year before the Environment Agency believed the offence was committed. These appear to show a large burned area on the land at this time and might be evidence that the illegal activity had been ongoing for a longer period of time than the investigators previously thought. This highlights the practical function of imagery archives for prosecuting authorities. If they had access to such imagery, then they might have used this in court to press for a harsher sentence.

4. Transferring Theory into Applications

The case studies above demonstrate three clear examples where EO technologies might be used as an environmental enforcement tool. They can sometimes provide evidence of regulatory non-compliance, any damage done in physical

30 Taken from DigitialGlobe's Quickbird satellite which has 60 cm resolution. The two images in the top of Figure 4 are the same, except the image on the right has been magnified to show the burnt area more clearly.

terms, the location of an offence and the dates that the offence took place. They will not, however, be suited to all legal and regulatory needs.

4.1 Supporting Evidence

Not even the strongest supporters of EO technologies would suggest that they will ever overtake or even replace ground-based monitoring. Their potential should not be oversold, as their main value will be to supplement current enforcement methods. Few other technologically based enforcement tools work optimally in isolation—satellites are no exception, and the success of admitting EO data in court[31] will, in most cases, depend on supporting evidence. Many courts may be reluctant to permit the use of only one source of evidence as a basis for identification and some would be unlikely to convict solely on the basis of EO data alone. Lawyers would normally expect a judge to ask why, if there was a chance of a physical inspection, it was not taken. Some EO data will require more supporting materials in courts than others, but there could be cases with clear temporal issues, which would certainly put a greater emphasis on these technologies. The use of satellite data in court to show irrigation rights under Spanish water legislation is one of the few examples where the conflict between a prosecution satellite image and evidence from an individual defendant has directly been in issue.[32] The Spanish courts have, however, sometimes favoured evidence from satellite technology over human corroboration.[33]

4.2 Environmental Applications

The examples above illustrate some potential legal applications, but for its use at a more general operational level, EO technology might not yet have reached a level of sophistication where it could be considered suitable for monitoring all forms of environmental laws. In general terms, EO technologies are obviously by their nature most useful at monitoring activities taking place outdoors. They are clearly not suitable for seeing what is taking place inside buildings and, as such, ground-based inspections would have to continue. It is also conceivable that, in terms of monitoring some outside activities, the

31 This article does not cover, in depth, issues of EO data in the context of evidential rules and procedures. For a more thorough examination of the evidential implications of using satellite data, see R Macrory and R Purdy, 'The Use of Satellite Images as Evidence in Environmental Actions in Great Britain' (2001) 51 Droit Et Ville 69.

32 Tribunal Superior de Justicia de Castilla-La Mancha (Sala de lo Contencioso-Administrativo, Sección 1ª). Sentencia Núm. 376/1998 de 11 Mayo.

33 Ibid. See also R Macrory, 'Technology and Environmental Law Enforcement' in G Winter (ed) *Recht und Um-Welt* (Europa Law Publishers, Amsterdam 2003) fn 9 434; European Commission (n 22).

technology could be too imprecise to provide the specific legal data required; it could be too inflexible to react to specific events, it may not be relevant where there is a need to measure small quantities of pollutants (eg chemical concentrations—a feature of many environmental laws) or conventional means of obtaining evidence, such as ground-based inspections, might simply be more cost effective, or indeed preferable, depending on what was trying to be achieved.

The quality of data coming from EO technologies that could be useful for lawyers depends on each individual case and the kind of application that is required. There has been very little analysis and published information so far as to which specific environmental laws could be monitored by EO technologies. To test which specific environmental laws are best suited to this form of regulatory monitoring, 106 EU laws and 42 international laws were examined in a University College London (UCL) research project.[34] This revealed that EO technologies could, in theory, provide an evidence function for many of these, and that there was a significant amount of environmental legislation that could be monitored this way. Six detailed case studies were also undertaken to analyse whether satellites could be used to successfully monitor environmental laws covering waste legislation and unlicensed sites, protection of nature areas, atmospheric emissions, oil pollution and climate change.[35]

One core example of one of these case studies, demonstrating where EO technologies can be deployed in a future compliance context, is monitoring protected areas, such as sites of special scientific interest (SSSI) in the UK.[36] High-resolution satellite imagery can clearly see these sites and can monitor some of the 'operations likely to damage'[37] (OLDs) in them. Whilst EO technologies could see OLDs such as vegetation and grazing changes, watercourse modifications and the destruction of roads and tracks, they currently do not have the capabilities to monitor all OLDs; for example, the killing or removal

34 The UCL project undertook a short survey of European and international environmental laws to assess their suitability for satellite monitoring. Legal and technical researchers looked for matches between the technical capabilities of satellites (existing and potential) and the objective and legal requirements of the environmental laws. If there was potential scope for satellite monitoring, then we examined factors such as: Existing monitoring; whether it could catch someone in the act or provide historical data; whether it could indicate a problem and any pitfalls? See further, 'Project Publications' (UCL, AHRC Satellites and the Law Webpage) <http://www.ucl.ac.uk/laws/environment/satellites/index.shtml?proj.publications> accessed 26 May 2009.

35 This research examined if satellites could alert regulators to specific breaches, provide direct evidence in judicial proceedings, provide direct evidence in negotiating sanctions (eg when the activity started and its frequency), or monitor compliance with a court order or sanction. See further, 'Project Publications' (UCL, AHRC Satellites and the Law Webpage) <http://www.ucl.ac.uk/laws/environment/satellites/index.shtml?proj.publications> accessed 26 May 2009.

36 Protected in the UK under The Countryside and Rights of Way Act of 2000.

37 OLDs are a list of activities that are not allowed to take place within the SSSI.

of wild animals. The technology is, therefore, clearly not suited for monitoring all types of activities, though it could still be useful, as it allows for regular monitoring of many of the operations which could damage SSSI sites.[38]

4.3 Compatibility with Legislation

Each environmental law has quite different characteristics, requiring different forms of monitoring. Air pollution, for example, could in theory be monitored using EO, but most current satellite-based sensors cannot measure constituents of a polluted atmosphere and the technology is still in its infancy in terms of the capabilities for doing this.[39] In terms of compatibility with most environmental legislation, EO technologies are not currently developed with the legal sector in mind. For example, in the context of air pollution, EO is generally not capable of the temporal sampling and averaging necessary to determine exposure over short timescales. Much of the air pollution legislation in place in the EU, for example, also requires monitoring at ground level, meaning that the use of EO would be incompatible with monitoring requirements under existing laws. This, of course, does not mean that current laws cannot be changed, or future laws developed, with EO technologies in mind.

4.4 Temporal Dimension of EO

As demonstrated above, EO technologies can have a clear use as historical evidence, providing impartial analysis of the timing of an activity. In a planning law context, for example, it might be possible to demonstrate a change of use or the timing of construction of an unauthorised building. In international litigation, satellite imagery showing demarcation changes in boundary dispute cases has been offered as evidence before the International Court of Justice.[40] EO images taken over a period of years, showing changes over time in the locations of villages and other installations, in agricultural use, in river courses or the erosion or accretion of coastlines, have been

38 'Case Study Four: Monitoring Habitats and Protected Areas' (UCL, AHRC Satellites and the Law Webpage) <http://www.ucl.ac.uk/laws/environment/satellites/docs/20_habitats.pdf> accessed 26 May 2009.

39 The US space agency, NASA, planned to launch their first spacecraft specifically dedicated to mapping carbon dioxide in 2009. See Amos (n 8). This launch, in February 2009, was not a success and it crashed shortly after launch. See A Vaughan, 'Nasa's C02 Satellite Crashes into Antarctic Ocean' (BBC News Website, 24 February 2009) <http://news.bbc.co.uk/1/hi/sci/tech/7907570.stm> accessed 30 June 2009.

40 See the following International Court of Justice cases: [i] *Maritime Delimitation and Territorial Questions between Qatar and Bahrain* (Qatar and Bahrain) (1995) ICJ Report 6 [ii] *Case concerning the Land and Maritime Boundary between Cameroon and Nigeria* (2002) ICJ Report 303 [iii] *Case concerning Kasikili/Sedudu Island (Botswana/Namibia)* (1999) ICJ Report 1045.

considered by the Court.[41] EO data could also enable a person charged or suspected of committing an offence to prove that the offence occurred at a different time.

Google Earth already allows access to vast amounts of archived EO data free of charge on the Internet, and this has resulted in some cases where the police have been alerted to possible drugs offences.[42] Investigating officers at the Environment Agency have also used Google Earth in surveillance operations, using the data to plan entry and exit points and monitoring positions.[43] Google Earth does, however, have limitations in legal terms, primarily because the user does not know the history of the image, such as where it came from and the date it was taken. In one case in a US court, it was dismissed as evidence for not reaching the required levels of evidential proof.[44]

Getting evidence or information from Google Earth is, however, just the tip of the iceberg in terms of legal information opportunities. A major benefit with EO technologies, and one that is unique in its scale and timing, is the fact that many images are saved to an archive. Imagery collected by most commercial satellites can be stored and archived in archive data banks, which can be purchased from image suppliers by anyone. In most circumstances, all that is needed are the geographic coordinates and dates, and one could access online satellite distribution catalogues to see if there is matching imagery for one's needs.

At present, there could be some difficulties for environmental lawyers wishing to access archived EO data. Archives do not have universal applicability and there is no common searchable database covering all major satellite suppliers at the current time. Anyone wishing to get hold of an image in an archive will have to access individual distributors' websites. Distributors' websites are also not designed with non-technical people in mind. First-time users might find it difficult and frustrating locating the information they require. Some large regulatory bodies, like the Environment Agency, have technical personnel with EO experience already in place in their organisations, who can advise, although legal staff might not be aware of this. For other regulatory agencies with no such technical expertise and support, external bodies that could assist in acquiring imagery might have to be consulted.

Although there are extensive archives and catalogues, it is still not possible to have access to all historical satellite data. Whilst satellites are constantly

41 See NPA Group, 'Applications of Earth Observation to the Legal Sector' (BNSC Sector Studies Programme Report, 2001).

42 'Swiss police google farmers, find marijuana field' (Associated Press Website, 29 January 2009) <http://www.ap.org> accessed 26 May 2009.

43 Statement by Owen Bolton, Environment Agency (Personal communication, 4 September 2007).

44 re: Kaminsky House Replacement Application, United States, State of Vermont Environmental Court, Docket number 269-11-06, 29 November 2007.

collecting data, this information is not always kept long-term—primarily because of the massive computer data storage space requirements.[45] Because of storage difficulties, some archives only contain data that distributors think people will buy, so there is a far greater chance of archived images of cities than rural areas.[46]

If information about an activity that had taken place in the past, on a particular day, was required, in most cases it would be unlikely that EO imagery would be available.[47] Relevant factors include the timing of satellite passes, weather conditions (which affect visibility) and whether a recorded image has been saved to an archive. It is sometimes possible to get archived satellite imagery covering a very specific or tight time period, but this often comes down to chance. For example, insurance investigators charged a couple in New Orleans with insurance fraud after satellite images taken immediately after Hurricane Katrina revealed that the damage to their house actually occurred after the Hurricane.[48] Images were purchased after investigators considered that the damage did not look like other Hurricane damage and appeared to be man-made. However, this is clearly not the norm, and getting an archived image covering a short time-span will normally require luck.

Monitoring polluting activities where the temporal dimension is tight, such as oil pollution discharges from tankers at sea,[49] could therefore be difficult using orbiting satellites. If one only required a snapshot of an activity taking place over a longer period of time, like the landfill example in Figure 4, it would be easier to find relevant imagery. Although the temporal dimension can be a constraint in legal terms, many environmental activities could still be monitored in practice. It seems likely that EO archives will also get more substantial and better organised as time moves on and commercial markets intensify.

45 High-resolution imagery takes up large amounts of data-storage room, similarly to digital cameras when a higher pixel size is used to take a photo.

46 Research under the AHRC project demonstrated that there was difficulty getting imagery for quite a high number of rural sites where environmental prosecutions had taken place. Images of sites that were located closer to cities were found to be easier to obtain.

47 Research under the AHRC project found that it was sometimes hard for the images in the archive to correspond with the dates needed. This was the case for rural areas, as well as areas within, or close to, cities. To give a general example, satellite images from 3 May 2007, showing the Portuguese holiday resort where the child Madeleine McCann was abducted from could not be found. The nearest available high-resolution archived satellite image appeared to be from 30 May 2007. This illustrates the difficulties of a satellite taking a picture of an exact location at an exact time.

48 Louisiana State Police (Insurance Fraud and Auto Theft Unit), '2006 Annual Report' (2007) 24 <http://www.lsp.org/pdf/ifuAnnualReport06.pdf> accessed 26 May 2009.

49 This form of monitoring is allowed under Resolution IMO A 152 of 17 November 1983, of Parties to the Protocol Relating to the Convention for the Prevention of Pollution from Ships (adopted 17 February 1978, entered into force 2 October 1983) 17 ILM 246 [MARPOL 73/78].

5. Changes in Environmental Regulation

Current methods of environmental regulation and enforcement have made a substantial contribution to protecting the environment, but may not be so well suited to meeting future challenges. Much has already been written on what can be done to make regulatory regimes more effective and efficient,[50] but there has been very little analysis of environmental lawyers using new EO technologies. This article has already put forward an argument that EO technologies might work in a regulatory or evidence-based context in some situations. What is key to their future deployment is clear thinking as to whether they are actually needed in this context, or if they are a potentially expensive solution looking for a problem. Their stock might grow in this regard when one considers both current and future regulatory challenges in the environmental sector.

5.1 'Career' Criminals

Breaches of environmental laws are often portrayed as either being as a result of unfortunate accidents attracting strict-liability prosecution, or as being corporate white-collar crime.[51] Whether this paints an accurate picture of previous failures of compliance or not is arguable, but in the last decade, with increased environmental regulation and taxes, we have certainly seen the emergence of more blatant criminal operations.[52] Dangerous characters and career criminals are now involved in some of our most serious environmental crime. At times, Environment Agency officers have to be accompanied by police officers when investigating premises, as firearms can now sometimes found at the scene of the crime.[53]

Whilst the Environment Agency has some powers to enter premises, occupants at unlicensed or illegal sites may refuse entry, and the investigating officer might need to get a warrant to enter the premises. Showing reasonable cause in getting a search warrant[54] might sometimes prove difficult. This is especially so for sites with high fences, where the investigating officers cannot see what is taking place behind them at ground level. This is also true for sites at secluded locations where public tip-offs are less commonplace, and where people are afraid to inform the authorities for fear of reprisals. As this new breed of environmental criminals pose a physical danger to

50 A Farmer, *Handbook of Environmental Protection and Enforcement: Principles and Practice* (Earthscan, London 2007) 2.

51 S Bell and D McGillivray, *Environmental Law* (6th edn, OUP, Oxford 2006) 287.

52 Statement by David Stott, Environment Agency (Personal Communication, 5 December 2008).

53 For example, the landfill prosecution shown in Figure 4 above.

54 The powers of entry and inspection in the UK in relation to this are in the Environment Act 2005 ss 108–110.

environmental investigators, EO technologies could be used to monitor suspected high-risk locations or sites.

5.2 Increases in Legislation

Contemporary environmental regulation has seen an unprecedented increase in the number and type of environmental laws for which regulatory bodies are responsible.[55] The sheer volume of environmental laws produced in the UK in the last few years, for example, is quite eye-opening, and particularly so when set against national government policies promoting deregulation.[56]

Many countries, including the UK, rely predominantly on 'command-and-control' style regulation, where the regulator issues permits, monitors and inspects activities, and where necessary takes appropriate enforcement action.[57] For example, the Environment Agency is responsible for more than 1,600 authorisations in process industries, 100,000 consents to discharge to inland waterways, 7,500 waste management licences and 4,900 water abstraction licences.[58] Issuing and managing an environmental permitting system of this size requires extensive resources and many activities require regular monitoring. In the financial year 2004/05 alone, the Environment Agency carried out 140,528 ground inspections,[59] although the annual number of inspections appears to have fallen since.[60] Command and control regulation can be a very powerful method where strict adherence to a standard is required, but faced with modern pressures it can also be insufficiently effective.[61] Traditional methods of ensuring compliance based on licensing and bureaucratic physical inspection regimes can increasingly be seen as blunt and resource intensive.[62]

55 R Macrory, *Regulation, Enforcement and Governance in Environmental Law* (Cameron May, London 2008) 7.
56 Ibid 353.
57 Farmer (n 50) 1.
58 Environment Agency, 'Delivering for the Environment: A 21st Century Approach to Regulation' (Environment Agency, 2005) 6.
59 Macrory 2006 (n 1) 17.
60 Statement by Joel Stern, Legal Services, Environment Agency (Personal email correspondence, 7 July 2009). The figure given above is based on a 4-year average of site inspections and audits undertaken by the Environment Agency. (i) 2005/06—163,657; (ii) 2006/07—138,936; (iii) 2007/08—128,749; (iv) 2008/09—43,080. These figures are based on financial years. There are fairly large discrepancies between the figures for different years, especially those for 2008/09 as compared to previous years. This is the result of methodology varying from year to year and between regimes. In some cases, the available figures relate to audits of sites and in others they count actual inspections. The advent of the Environmental Permitting regime also had an effect on the figures from 2008/09.
61 A Ogus and C Abbot, 'Sanctions for Pollution' (2001) 14 JEL 283.
62 See generally, N Gunningham and P Grabosky, *Smart Regulation: Designing Environmental Policy* (Clarendon Press, Oxford 1998).

Regulatory bodies are being forced to react to shifting dynamics in the development of environmental laws. Conventional inspection and enforcement approaches are increasingly unlikely to meet contemporary policy requirements, which can be more physically extensive in area, as is the case with habitat or forestry protection. The issues being regulated are not only increasingly complicated, but also are applicable to a greater number of businesses. An example of this is that millions of farms across Europe now fall under the remit of EU waste legislation. We are also seeing the adoption of new regulatory techniques such as emissions trading. As we move from handling more familiar environmental pressures, to modern questions of resource and energy use, we will need to devise new regulatory responses.[63] The monitoring and enforcement opportunities presented by EO technologies could become increasingly important and appropriate.

5.3 Inspections and Risk-Based Regulation

While the volume of environmental laws increases, the numbers of staff charged with monitoring and enforcing them are often remaining static or decreasing. Public sector resource constraints mean that regular inspections, particularly in remote areas, are increasingly difficult to finance.[64] Some regulators have already begun reducing the number of ground inspections. In England and Wales, there has been a steady decline in the number of environmental inspections, with some at some industrial sites reported to have lowered by up to 50% over a 5-year period.[65] For example, the number of low-risk waste inspections by the Environment Agency has decreased from 120,000 to 80,000 a year.[66]

Within the context of budgetary constraints, an increasingly common regulatory response to dealing with contemporary environmental challenges has been to implement, the so-called flexible risk-based enforcement strategies. In line with the Hampton Review of inspection and enforcement in the UK,[67] risk-based regulation implies using what are often limited resources, in the most effective manner possible, to achieve specific policy outcomes. Rather than carrying out inspections to the same level of intensity on all of the activities falling within the scope of control, calculated assessments are made

63 Macrory (n 55) 8.
64 Macrory (n 33) 433.
65 Bell and McGillivray (n 51) 292.
66 House of Commons Environment, Food and Rural Affairs Committee, 'The Environment Agency', Seventh Report of Session 2005–2006, (HC 780-1, 11 May 2006) 14.
67 P Hampton, *Reducing Administrative Burdens: Effective Inspection and Enforcement* (HM Treasury, London 2005).

to target regulatory attention on where the risks are most likely; namely, the higher-risk operators with the worst environmental performance.[68] The US Environmental Protection Agency has similarly adopted an effective targeting approach to reduce the cost of ensuring compliance.[69]

As ground-based monitoring becomes less available, the targeting of resources in this way is a sensible approach, but there are risks that should the unexpected occur and perceived low-risk offenders flout the law. The use of EO, potentially, fits well with risk-based enforcement approaches, allowing regulators to target resources and on-the-ground monitoring at the more risky activities, whilst retaining some peace of mind that EO technologies might play a back-up monitoring and evidence-based role. Regulated communities could be told that whilst they might not always be directly inspected at ground-level, EO data was still collected regularly and archived data could be consulted to check historical regulatory performance. There is a long tradition of historical records being used by lawyers to resolve disputes and provide fresh evidence.[70] The use of EO data in such a way could, therefore, also be a powerful regulatory weapon for supervisory agencies wishing to complement risk-based enforcement approaches.

5.4 Financial Savings

Regulatory bodies increasingly have to cope with funding constraints that require them to reconsider their conventional ways of monitoring and enforcing environmental laws.[71] The allocation of regulatory resources in terms of personnel and funding already plays a critical role in environmental compliance and this could be affected further through economic recession. Such bodies are, therefore, in the difficult position of finding the regulatory 'holy-grail' of effective environmental monitoring with ever more constrained finances.

When compared with ground-based monitoring, it is conceivable that in certain circumstances, EO monitoring could offer financial savings. This has already been demonstrated in the agricultural sector in some cases. The British Potato Council, for example, has used satellite data to monitor fields growing potatoes in eastern England. They found that the accuracy was so good that it allowed them to replace field inspection with satellite mapping,

68 House of Commons (n 66) 14.

69 See generally, L Friesen, 'Targeting Enforcement to Improve Compliance with Environmental Regulations' (2003) 46 J Envtl Econ Mgmt 72.

70 For example, having access to historical archived records of legal proof was supported by Bentham, who called them 'preappointed evidence'. J Bowring, *The Works of Jeremy Bentham. Volume 6* (William Tait, Edinburgh 1843) 508.

71 Bell and McGillivray (n 51) 292.

and in the process, they reduced their field inspection staff from 92 to 16, translating to a saving of some £3 million per annum.[72]

Every year in Europe, approximately 5 million farming businesses declare more than 50 million agricultural parcels; claiming up to €56 billion each year on EU subsidies.[73] The initial responsibility for checking this expenditure for fraud and irregularities lies with the individual Member States, which must check a minimum of 5% of these claims in their own countries.[74] While this monitoring responsibility is with the individual Member States, the EU provides them with satellite imagery free of charge to assist them in fulfilling this requirement. The purchase of satellite data from commercial providers to check the minimum levels of claims in Member States costs the EU approximately €5 million each year,[75] but this can result in significant financial savings at national level compared to the cost of ground-inspections.[76]

5.5 Deterrent Effect

Environmental compliance is often measured by comparing the number of inspections with the number of enforcement actions, in order to garner insight into relative success of enforcement strategies. However, this does not paint a full picture as to the success of a given compliance strategy, and probably underestimates environmental performance in practice. Although inspections open up the possibility of non-compliance being detected, it is more likely that it is the actual threat of detection that encourages compliant behaviour.[77] Standard deterrence theory holds that the mere fact of conducting inspections, coupled with the probability of detection being credible, should increase the rate of compliance.[78]

Often cited in this context, Bowles considered that '20 percent of the regulated population will automatically comply with any regulation, 5 percent will attempt to evade it, and the remaining 75 percent will comply as long as they think that the 5 percent will be caught and punished'.[79] If this theory

72 R Harris, 'Area Estimation of the British Potato Crop' (Report to the British National Space Centre, ADP2-UCL-RPT-004, 1999).

73 Statement by Simon Kay, JRC European Commission (Personal Communication, 24 June 2009). See also, R Purdy, 'Earth Observation and Agricultural Monitoring in the EC' (AHRC Report 2, 2008) <http://www.ucl.ac.uk/laws/environment/satellites/docs/2.AHRC.Agriculture.pdf> accessed 26 May 2009.

74 Regulation 796/2004 (n 21).

75 Statement by Simon Kay, JRC European Commission (Personal Communication, 5 December 2007).

76 Statement by Chris Lee, UK Rural Payments Agency (Personal Communication, 4 December 2007).

77 Farmer (n 50) 115.

78 For example, RA Posner, 'Gary Becker's Contribution to Law and Economics' (1993) 22 JLS 211.

79 C Bowles, *Promises to Keep: My Years in Public Life 1941–1969* (1st edn, Harper and Row, New York 1971) 25.

holds true, then modern concepts of risk-based regulation and the targeting of those who are most likely to seek to evade the law could bring about better overall compliance. Alternatively, if the general level of numbers of on-site visits by regulators drops further, then this could undermine it as a method of changing compliance behaviour.[80] By targeting the 5% group, the lack of credible monitoring of everyone else might not engender confidence in the effectiveness of environmental regulation amongst the 75% group.

Some incidents of non-compliance might be more effectively deterred if those regulated thought that they were being permanently monitored. This has been argued since Bentham's Panopticon theories, where he considered that 'the more strictly we are watched the better we behave'.[81] With this in mind, it is possible that EO could act as an increased deterrent over conventional inspection approaches, becoming a new creative means to influence potential criminal behaviour. It might have a higher deterrent effect than some other technology-based enforcement approaches, such as speed cameras or CCTV, because it is, by its nature, covert. Regulators could have a tool where the regulated can be made aware that they could be watched at any time, but they cannot actually tell whether in fact they are being monitored.

This continuous type of monitoring might enhance the capacity of regulators to promote the type of proactive environmental inspection advocated by Hutter,[82] whilst also offering them the type of credible deterrence threat advocated by Silberman.[83] Regulators could create the impression of a substantial capability and threat of enforcement with only very limited regulatory resource commitment. Exploiting the gap between 'perception and reality'[84] in this way could enable greater successes when combined with risk-based regulatory approaches.[85]

There has been little research into whether mere knowledge of being monitored by EO technologies could lead to positive compliance outcomes, in terms of influencing the behaviour of those subject to regulation. Does satellite monitoring 'press the right buttons' in terms of having higher deterrence effect and influencing compliance behaviour? The only economic group regularly monitored by satellite in the UK are farmers in connection with EU subsidy payments. A UCL survey conducted in 2008 found that farmers

80 See generally, N Gunningham and D Sinclair, *Leaders & Laggards. Next-Generation Environmental Regulation* (Greenleaf Publishing Limited, Sheffield 2002).

81 M Quinn (ed), *The Collected Works of Jeremy Bentham: Writings on the Poor Laws, Volume 1* (Clarendon Press, Oxford 2001) 277.

82 BM Hutter, *Compliance Regulation and Environment* (Clarendon Press, Oxford 1997) 150.

83 JD Silberman, 'Does Environmental Deterrence Work? Evidence and Experience Say Yes, but We Need to Understand How and Why' (2000) 30 ELR 10523.

84 Gunningham and Sinclair (n 80) 34.

85 See Abbot (n 2) for a good discussion on deterrence and environmental enforcement strategies generally.

claiming subsidies did not have a clear idea of how regularly they were monitored by the satellite.[86] They found that they greatly overestimated both the percentages of farmers monitored this way annually, and the number of actual checks made by the satellite. This method of monitoring also appears to have had a strong influence on compliance behaviour, as significantly, over half of all the farmers surveyed thought that this form of monitoring was acting as a deterrent.[87]

Although EO technologies might dramatically improve the ability of regulatory bodies to detect and deter in the short term, questions can be raised as to whether reverse changes in behaviour might occur if those regulated this way were made aware of the actual levels of monitoring over the long term. There is a possibility that this method of compliance could fall like a 'house of cards' if true monitoring figures were ever made public.[88] Although there is a risk of this, it still seems likely that the potential of EO to act as a basic, cost-effective deterrent, will progressively catch the attention of regulators seeking new enforcement strategies.

5.6 Monitoring with the Least Amount of Interference

Although many countries, including the UK, have seen moves towards deregulation, industry still often believes that it is burdened by too much regulation.[89] EO technologies might be a next-generation tool that could compliment the ideals of optimal enforcement.[90] Whilst it is impossible to reduce the regulatory effort to zero, EO technologies, if used judiciously and applied in appropriate circumstances, could play an enhanced role in providing compliance monitoring at a distance, checking regulated communities without disturbing them.

Use of EO technologies in environmental enforcement has the potential to polarise opinions. Although we are in an era of more pervasive technology, some regulated entities will dislike it on account of its 'Big Brother' characteristics, even though comparable data is publicly accessible on Google Earth. Conversely, others will embrace it and prefer it to ground-based checks. In certain situations, it may be considered to lead to improved cooperation

86 Survey under the AHRC Satellites project at UCL. Two hundred and two completed surveys were received from farmers in the UK. The full results of this survey are forthcoming.

87 Ibid.

88 For example, if there was whistleblowing, or an approved disclosure under freedom of information laws. However, s 31 of the Freedom of Information Act 2000, in the UK, provides an exemption to disclosure of information held by a public body, if its disclosure would, or would be likely to, prejudice, inter alia, the prevention or detection of crime or the administration of justice.

89 House of Commons (n 66) 14.

90 G Stigler, 'The Optimum Enforcement of Laws' (1970) 78 J Pol Econ 526.

between regulators and the regulated community, especially if it increased the opportunity for even-handedness and equal treatment in monitoring and enforcement, as envisaged by Macauley and Brennan.[91] Satellite monitoring might also be attractive to regulators and the regulated community if it could further reduce the need for conventional regulatory inspections for some environmental laws, as monitoring data can be archived and consulted if needed later. A reduction in inspections might be seen to be more acceptable if satellite-monitoring data was made publicly accessible, encouraging credible use, since other parties could check the veracity of the data.[92]

5.7 External Environmental Monitoring

The use of EO technologies goes beyond the exclusive domain of the State and has wider implications than its use by environmental lawyers alone. As discussed above, anyone can have access to EO technologies, creating new opportunities for monitoring. With greater environmental awareness, the involvement of non-governmental organisations (NGOs) in environmental issues has dramatically increased in recent years.[93] Aided by new methods of information gathering, they have become increasingly sophisticated in their methods of collecting evidence of wrong doing to assist them in communicating their message.[94] NGOs have already used satellite technologies to show evidence of human rights abuses in places such as Burma, Darfur and Zimbabwe, for example.[95] It may only be a matter of time before environmental NGOs seek to shape public opinion, lobby governments and pressure industry directly with environmental information obtained from EO technologies.

A variety of other commercial third parties might also increasingly begin to take a far greater interest in EO technologies. The New Orleans insurance fraud case, discussed above, is a good example of this. Banks and insurance companies might seek to minimise their financial risk and protect their investments by scrutinising more closely the environmental credentials of their

91 M Macauley and T Brennan, 'Remote Sensing Satellites and Privacy: A Framework for Policy Assessment' (1995) 4 Law Comput Artificial Intell 233.

92 M Macauley and T Brennan, 'Enforcing Environmental Regulation: Implications of Remote Sensing Technology' (Resources for the Future, Discussion Paper No. 98-83, 1998) 42.

93 See ch 6, Zaelke, Kaniaru and Kružiková (n 3).

94 Gunningham and Sinclair (n 80) 190.

95 Satellite images have been used to show the destruction of crops, houses and settlements by burning and bulldozers. NGOs believe that these images provide strong evidence of mass refugee displacement. For example, see (i) 'Zimbabwe demolition images shown' (BBC News Website, 31 May 2006) <http://news.bbc.co.uk/1/hi/world/africa/5032156.stm> accessed 26 May 2009; (ii) L Howey, 'Satellites track "removed" Burma villages' (BBC News Website, 17 November 2007) <http://news.bbc.co.uk/1/hi/world/asia-pacific/7099713.stm> accessed 26 May 2009.

clients. EO could be used to provide financial assurance on climate investments in Clean Development Mechanism projects,[96] or rainforest protection schemes, in developing countries. An audit style tool to check that money has been correctly spent could be attractive to financiers and governments who did not wish to travel to sites to verify these types of projects.

5.8 Public Confidence and Communication

Having visibly effective enforcement is essential, not only to achieve the environmental outcomes implicit in the legal requirements, but also to ensure public confidence in the legal system. A leading element contained in principles of natural justice is that justice is seen to be done.[97] Whilst moves towards adopting risk-based enforcement approaches might make regulation more refined or efficient, such publicised reductions in monitoring might also cause controversy and public concern. A recent UK Government inquiry revealed that the Environment Agency decided that half a million potential new low-risk hazardous waste producers did not need to register with them, saving the producers around £14 million a year.[98] It is questionable whether the public will have confidence in such decisions, which could simply be seen as disguising a reduction in monitoring and enforcement activity only to save money.[99] Any major accident or environmental incident that might occur, where monitoring had been deemed not to be required, or where it had not taken place for a long time, could publicly question or undermine confidence in the enforcement role of the Agency.

In an era of less visible legal monitoring, the use of EO technologies might help reduce scepticism in existing systems and secure public confidence in environmental regulation. Disclosure of pictures taken from EO technologies, showing environmental offences, could be a new cornerstone in contemporary rights to information and public participation. The social context of regulation is already changing, with the public demanding greater accessibility of information and accountability of public bodies. Regulatory bodies have also recognised this and the Environment Agency, in 1999, controversially started adopting a tactic of 'naming and shaming' companies that had committed environmental crimes.[100] Similar schemes also operate in other countries for

96 The Clean Development Mechanism (CDM) is the first international attempt to address climate change using global-emissions trading market mechanism involving both developed and developing countries. For more information see <http://cdm.unfccc.int/index.html> accessed 30 June 2009.

97 GA Flick, *Natural Justice: Principles and Practical Applications* (Butterworths, Sydney 1979) 120.

98 House of Commons (n 66) 14.

99 Bell and McGillivray (n 51) 292.

100 'UK Polluters in Hall of Shame' (BBC News Website, 22 March 2009) <http://news.bbc.co.uk/1/hi/uk/300702.stm> accessed 30 June 2009. The Environment Agencies 'Spotlight

non-compliance or poor environmental performances.[101] Furthermore, the enhanced use of public registers and on-line databases enables the public to find out more about licences, enforcement and local environmental conditions.[102]

The 2006 Macrory Review[103] and the UK legislation adopting these principles, the Regulatory Enforcement and Sanctions Act 2008, contain interesting parallels with how the use of EO technologies may fit in with changing agendas of public participation and regulatory justice. The Macrory Review examined 'publicity orders' as a sanction. These are similar to the 'naming and shaming' policy of the Environment Agency, except a court or independent tribunal would impose them upon conviction. This Review found that these orders could be a very effective means of deterring regulatory non-compliance.[104] Research from the USA also supports the fact that 'naming and shaming' environmental compliance as an adjunct to other enforcement activities could generate important pressure for compliance and improved performance.[105] EO could be included in these publicity orders, with images showing offences being committed and, in particular, their scale. There has been massive worldwide interest in new media technologies, such as Google Earth, and the use of EO in this way might also catch the public's imagination, bringing greater public involvement and transparency to the regulatory process.

The Macrory Review also considered adopting profit orders[106] and principles of restorative justice into a more effective system of sanctions.[107] Again, EO could fit in well with such holistic processes, in that it might be able to

on Business Environmental Performance' report shows the top 10 fines as a result of prosecutions. See <http://www.environment-agency.gov.uk/research/library/publications/34137.aspx> accessed 24 July 2009. See also P De Prez, 'Beyond Judicial Sanctions: The Negative Impact of Conviction for Environmental Offences' (2000) 2 ELR 11. The author in this article surveyed Environment Agency staff. The survey found that 49% of Agency officers felt that adverse publicity was the most important consequence of prosecution, compared with 20% who felt that the fine was the most important.

101 For example, Canada. See J Foulon, P Lanoie and B Laplante, 'Incentives for Pollution Control: Regulation and Public Disclosure' (2002) 44 J Envtl Econ Mgmt 169.

102 For example, in England and Wales, the Environment Agency have, 'What's in your Backyard?' <http://www.environment-agency.gov.uk/homeandleisure/37793.aspx> accessed 24 July 2009; and 'State of the Environment' <http://www.environmentagency.gov.uk/research/library/publications/34019.aspx> accessed 24 July 2009.

103 Macrory 2006 (n 1).

104 Ibid 84.

105 See C Rechtschaffen and DL Markell, *Reinventing Environmental Enforcement and the State/Federal Relationship* (Environmental Law Institute, Washington DC 2003) 265. They recommended that the EPA should begin publicly spotlighting the best and worst facilities in various industrial sectors. They thought that this form of performance ranking could be done using the data contained in the EPAs Sector Facility Indexing Project (SFIP), and envisaged that this could be similar to the Environment Agencies Spotlight on Environmental Performance (discussed in n 100).

106 Macrory 2006 (n 1) 74.

107 Ibid 69.

provide evidence of the repercussions and obligations created by non-compliance with a view to putting things right. The temporal basis of EO might provide historical data as to what damage was caused, when it was caused, what needs to be done to restore a site to how it was before the non-compliance occurred, and to identify any profits made from non-compliance. For example, if the court in the landfill case above had access to the satellite images in Figure 4, then this might have provided evidence that the offence had taken place over a much longer period, with greater profits. Publishing EO data could be a novel method of visually communicating to the public the magnitude of the offence and sanction, and could also be an effective way of promoting the principles of restorative justice, through displaying the outcomes of clean-up operations.

6. The Future Use of EO

In the last few years, there have been an unprecedented number of reviews across the world examining how we can improve current methods of environmental regulation. In the UK alone, there have been high-level reviews into the establishment of environmental courts and tribunals, and reforming sanctions.[108] What remains equally important is that the quality of enforcement inherent in the more formal legal structures is not lost in these evolving reform processes.[109] Without effective monitoring and enforcement, there is no credible deterrent in place and environmental law drifts into mere symbolic reassurance.[110]

The use of EO data by environmental lawyers is clearly at an early stage and has so far scarcely been utilised and tested. In the context of questions over the adequacy of resources and public acceptability of new risk-based enforcement methods, there is a compelling argument that EO could become an important tool in the future application of modern environmental laws. Its potential contribution in this area is likely to be increasingly recognised, especially if the step-changes in the technology continue at such breathtaking pace.

Modern technology is already extensively used in regulation. For example, sophisticated technologies already allow water quality and discharges of effluent to the aquatic environment to be automatically monitored, providing an automatic alert of non-compliance.[111] Clearly, EO technologies also offer

108 See references in n 1.
109 R Macrory, 'Regulating in a Risky Environment' in M Freeman (ed) *Current Legal Problems 2001* (OUP, Oxford 2002) 647.
110 Macrory (n 55) 711.
111 W Howarth, 'Self-Monitoring, Self-Policing, Self-Incrimination and Pollution Law' (1997) 60 MLR 200.

something new and flexible in terms of monitoring and enforcing environmental laws. However, they should not be oversold, as they cannot monitor everything and will not be appropriate for all types of environmental regulation. Like the technologies used for water quality monitoring, EO will not be used in isolation and a combination of regulatory strategies will almost certainly have to be used and retained.

There has been growing recognition amongst policymakers across the world that EO could provide information for evidence-based policy decisions concerning environmental conditions.[112] However, this relates to EO use for monitoring in the environmental sphere, rather than regulatory, enforcement and monitoring strategies. It is clear that environmental lawyers have yet to play a major role in any of the ongoing technical and policy discussions on satellite monitoring of the environment, taking place, both within Europe and internationally. Without wishing to attach blame as to why they are outside this process, they could in the future be more innovative and forward-looking, taking the initiative themselves and seeking greater engagement. Unless environmental lawyers are prepared to engage with EO technical and policy specialists, integrating new technologies in this field is likely to be stymied. Technical specialists must also adapt, learning to communicate information about complex technical information in a logical and concise manner that can be readily understood by lawyers and decision-makers. With this form of cooperation, EO technologies could be developed with the legal sector in mind, rather than the technology looking for a home after development, which is so often the case as things currently stand.

The greater use of EO data in legal and regulatory strategies, therefore, demands significant shifts in the mindsets of environmental lawyers. Strong advocates for these new technologies who can persuade others of the utility of the data and information will be needed. Generally, the success of introducing new forms of technology relies upon establishing a confidence base amongst those who might use it. This can sometimes take time. Precedents will be needed as further evidence of effectiveness, reliability and cost. Models of cooperation, towards sharing information and experiences with EO data should, therefore, be established between national regulatory bodies and other environmental enforcement networks worldwide.

112 For example, the Intergovernmental Group on Earth Observation is leading a worldwide effort to build a Global EO System over the next 10 years, examining how satellites can contribute to developing greater understanding of environmental factors and then improving the management and legal protection of them. The European Commission and European Space Agency have also established the Global Monitoring for Environmental Security project in Europe, whereby EU governments must develop satellite-derived information to monitor environmental conditions and pressures.

Environmental governance is increasingly seen as adaptive to modern challenges, and a sea change in approaches to compliance is already under way. At the same time, new technologies like EO are improving quickly, and, as this article has demonstrated, we are seeing dynamic changes in what they can now offer regulators and environmental lawyers. It might not be too long, therefore, before we see a more widespread adoption of EO technologies into legal and regulatory strategies in the environmental sector.