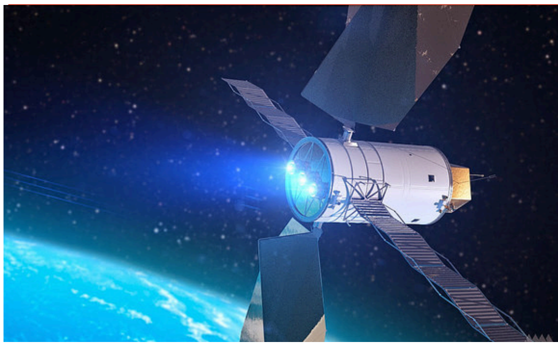


Eye in the sky: predicted future issues of the proliferation of commercial remote sensing

James Kilroe, Judge Business School, University of Cambridge

On October 24, 1946, the United States of America launched a captured Nazi V-2 rocket into sub-orbital space with a camera on-board [1]. This camera produced the first known image of the earth from outer space [1]. Presently, a few countries have easy access to satellite images; however, due to technological advances, the access to these images will soon become ubiquitous as new low cost satellites increase the access to space by developing nations and even commercial start-ups [2]. This expanding access poses risks due to the dual nature of remote sensing – it can have both military and civilian uses. An image that is used to monitor a pipeline could just as easily be used to plan an attack on said pipeline. This paper examines the potential security concerns of commercial remote sensing and how the current methods of regulation will need to change to keep abreast of the new technological developments.

Governments first ran the satellite remote sensing industry by heavily subsidising its high costs. However, due to recent technological improvements, the industry is now a burgeoning commercial market [3]. In the 1970's, the first commercial remote sensing companies were started as state-owned enterprises [4]. Landsat and later SPOT were the American and French attempts at providing commercially available remote sensing data [4]–[6]. In the 1990's, privately owned companies started to enter the remote sensing market – DigitalGlobe (formerly Orbital Imaging Corporation) pioneered this market and is still successful today [7]. However, in the 1990's, the market still suffered from high barriers to entry – such as the high cost of building and launching a satellite [8]. The recent small satellite revolution has drastically reduced these barriers [8]. This revolution is a result of access to cheap, miniaturised and evermore powerful electronics [9]. Now, a satellite that weighs 100 kilogrammes can produce pictures of the same quality as an equivalent 2200 kilogramme satellite from the 1990's [8]. The lowering of entry barriers has caused a rapid expansion in the remote sensing market, with the new forerunners being PlantLabs and Terrabella [10–12].

Small, cheap satellites produce images of similar standard to traditional satellites. There are four resolutions – spatial, spectral, radiometric and temporal – these govern the usability of satellite images [13]. The spatial resolution of the image determines whether one pixel on the image is equivalent to 1 metre on the ground or 1000 metres on the ground. This determines the usefulness of a picture – weather forecasting can be achieved with low spatial resolution (greater than 1 kilometre per pixel), but for activities such as town planning, 1 metre spatial resolution is required. At this detail a car (or tank) could be distinguished from a building. Modern small satellites are capable of producing images with a spatial resolution of 1 metre, which is equivalent to conventional old satellites [14]. This is satisfactory for most requirements and thus, the images from small satellites are now as useful as traditional large commercial satellites. Two other resolutions are spectral and radiometric, which relate to image gradient and colour detail respectively, however these are similar for large and small satellites.

The biggest improvement of small satellites is the temporal resolution, which is also known as the 'revisit time' i.e. how often a satellite can fly over the same location of the earth. This depends on the orbit of the satellite; a single satellite will have a revisit time of weeks or months. However, satellites in a constellation can rapidly reduce this time. But, large satellites can cost over $800 million each and thus are generally too expensive to launch in constellations [15]. However, small satellites are cheap and thus many can be launched. This can create a constellation of satellites with a revisit time of hours or even minutes [14]. Thus, updated images can be provided in almost real time. In comparison, through free software such as Google Earth, images with a spatial resolution as low as 15 centimeters, already exist [16]. However, the temporal resolution of these free images is generally years. Real-time imagery has the potential for a number of revolutionary and beneficial uses, but also has the potential to be used in a sinister manner.

The civilian uses for this type of application have significant potential, and many future uses have yet to be explored because this platform is so new. Current commercial applications include precision farming, resource management and the monitoring of illegal activities such as fishing and logging [17]. The technology could be used to monitor government action on the issues such as the Brazilian's inaction on illegal logging. Another example could be refugee monitoring, where it could help the European governments monitor the current migrant crisis and help plan their aid delivery. It can even be used to improve weather predictions. These are just three of the many uses that have the potential to impact billions of people. However, not all uses of this technology will necessarily be positive.

There is a large amount of uncertainty surrounding some of the hypothesised applications of this technology. For example, during future conflicts, news channels would be able to show real-time satellite images of battles, with results being difficult to predict. During the recent Ukraine and Russia dispute over Crimea, it was not clear to the public if Russian troops were in Ukraine or if it was separatist rebels as Russia claimed [18]. If news agencies had access to real-time satellite images, they would have been able to verify whether it was in fact the Russian army in Crimea, which may have put tremendous public pressure and a NATO obligation on Western governments to assist the Ukraine. On the other hand, there are some clear malicious uses for remote sensing data. Terrorists could use a real-time image to discover vulnerabilities in the security of an event as it unfolds and use these weaknesses to attack. Global real-time satellite imagery and a live battle map, available to both sides, would reduce the current intelligence advantage of established military powers over paramilitaries. So the question is: How can remote sensing be regulated to best maximise the advantages and decrease the negative effects of this new technology on the rights of all humanity?

The Outer Space Treaty, signed and ratified at the United Nations (UN) in 1967, is the basic framework of international space law, and as such it also governs remote sensing [19]. Article II of the Outer Space Treaty stated: "Outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means" [19]. This means it is illegal for any country to claim 'outer space' above their country, like country airspace is controlled, and thus it is legal for any country or company to photograph any part of the earth using satellites.

Although it has been legal for satellite images to taken over any country, different countries have introduced different methods to prevent the distribution of undesirable images. The first method of controlling satellite images was called 'shutter control' and was pioneered by the U.S. in the 1990s [20]. Shutter control allows the U.S. government to prevent local commercial companies from taking images of certain areas during wartime. The idea behind shutter control was to prevent U.S. commercial companies selling any potential damaging images to the enemy during wartime. Interestingly, Israel has managed to obtain a longstanding shutter control agreement with the U.S. government. Under the agreement, it is not possible for a U.S. commercial imaging company (such as DigitalGlobe) to sell images of Israel that exceed the quality of international suppliers (such as SPOT) [21, p. 166]. Furthermore, through separate negotiations with SPOT, the Israeli government has restricted the distribution of any sub-two-metre images of Israel [22]. However, as more imaging satellites are launched, it is becoming progressively harder for Israel to maintain this restriction. The GoTurk satellite, a Turkish satellite, is hoping to obtain sub-metre resolution images of Israel, which poses a potential risk to Israel [22]. The U.S. invasion of Iraq in 2003 was before many non- U.S.-based companies launched their satellites. Many of the new companies are from countries which are not known allies of the U.S. (e.g., Russia or China). These companies could publish sensitive images of war zones without the permission of the U.S.. The U.S. and other countries will thus confront newfound risks due to the broader distribution of remote sensing capabilities in future conflicts.

Another method used to prevent images being released is contractual agreements. At times, the U.S. government has exclusively purchased all available images over a certain area – such as over Afghanistan and Pakistan during its bombing campaign after the terrorist attacks on September 11th, 2001 [23]. Israel obtained contractual rights by providing advanced technology to the French SPOT satellite in exchange for an imaging blackout zone over Israel, but they failed to secure such an agreement with the GOTurk satellite [22]. As more providers enter the market, it is now impractical (and very expensive) to obtain contractual rights to all the commercial images of one region.

Currently, no individual country can implement effective preventative policies. Any new policy must be secured through international treaties at the UN. The two current UN remote sensing treaties are the International Charter on Space and Major Disasters and the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) [24, 26]. Both of these treaties are designed to provide satellite images to help with disaster relief. Countries can activate the charter during humanitarian disasters and it has been activated during events such as the 2003 Tsunami and the Malaysian M370 flight disappearance [26]. UN-SPIDER is designed to help developing countries plan for disaster management [25]. The key aspect of both these treaties is that they encourage access to remote sensing images rather than limit access. It would be extremely difficult to obtain an international treaty that limits images because of threats to individual militaries.

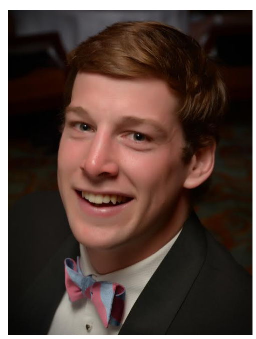
As civilian technology progresses and governments start to rely on commercial images, the difference between military and commercial images will begin to diminish, and local police in different countries will have to adapt to this new threat. However, is civilian access to military-grade technology bad? In 2000, the U.S. military was forced by congress to disable selective availability from the Global Positioning System (GPS) even though it was worried that civilian GPS's could be used to guide enemy missiles [27]. The only significant report of terrorist GPS use (and only as a personal navigation device) was during the 2008 attach in Mumbai [28]. However, there have been numerous positive uses of the GPS system from navigation of aircraft to the precision timing system of ATMs. On balance, GPS has become a tool for good and not an asset in the arsenal of terrorists as the U.S. military feared [29]. Remote satellite imaging will also have a net positive effect; already, remote sensing has improved land monitoring, weather predictions and even stock predictions through monitoring occupation levels in Wal-Mart parking lots. Overall, the civilian benefits will outweigh any negative uses and remote sensing will become so entrenched in everyday life, that it will become indispensable [30]. As with all new technology, policy decisions need to be decided to ensure that the technology maximizes its upside and limits its downside. These include:

1) allowing innovation; new technologies must not be curtailed because of possible corner cases, instead they must allow technology to develop with minimal regulation intervention. GPS been used in ways that were not imagined by the US military [29].

2) protecting the rights of individuals; for example companies should be prevented from monitoring the movement of individual cars or people without prior permission due to privacy concerns. Should states also be prevented from monitoring? What about monitoring foreign citizens in foreign countries?

We live in an ever-changing world, where technology has the ability to improve our world drastically. However, it can also cause damage. Like any new technology, there will be a period of uncertainty and adjustment as it is fully integrated into everyday life. Real-time remote sensing images will have an overall positive impact on our life. These images will drastically improve on currently available images. Regulations must change and adapt to match the new real-time capabilities of future satellite imaging constellations and in time the legal framework must be developed fully. Especially the international legal framework about how states can use the technology to monitor each other or each other's citizens. Furthermore, as this technology becomes internationally available, new international treaties will need to be formed to limit these images being obtained by groups that pose a threat to global security. These images could potentially become part of a UN arms embargos. Due to the lengthy nature of international treaty negotiations, the policy formation process must start as soon as possible to stay abreast of the rapid pace of technological development.

About the Author



James Kilroe has just completed an MPhil in Technology Policy at the Judge Business School. Previously, he completed both an MPhil in Space Studies and BSc in Mechanical Engineering at the University of Cape Town. He is passionate about all things technology, with his primary focus being space technology. He has done work for different high technology start-up companies, such as Marcom, where he helped design launch vehicle technology. He enjoys sports especially rowing, and rugby for which he received a Blue. In the longer term, he is hoping to join a venture capital firm with a focus on space startups.

References

[1] T. Reichhardt, "First Photo From Space", Air & Space Magazine, 2006: http://www.airspacemag.com/space/the-first-photo-from-space-13721411/.
[2] J. Kumagai, "9 Earth-Imaging Start-ups to Watch", 2014: http://spectrum.ieee.org/aerospace/satellites/9-earthimaging-startups-to-watch.
[3] Marketwire, "Remote Sensing Industry Expanding Commercial Opportunities, Reports BCC Research", 2016: http://www.marketwired.com/press-release/remote-sensing-industry-expanding-commercial-opportunities-reports-bcc-research-2113909.htm
[4] J. Achache, "Open Access to Earth Observation From Space: Opportunity or Threat to Security?", Stanford University, 2003.
[5] H. R. Hertzfeld and R. A. Williamson, "Societal Impact of Spaceflight", Government Printing Office, 2007.
[6] NASA, "Landsat in the President's NASA FY11 Budget Request", 2016.
[7] DigitalGlobe, "Our history", 2016: https://www.digitalglobe.com/about/our-company.
[8] Y. Xue, Y. Li, J. Guang, X. Zhang, and J. Guo, "Small satellite remote sensing and applications – history, current and future", Int. J. Remote Sens., vol. 29, no. 15, pp. 4339–4372, 2008.
[9] Lorenz, R, "All satellites cheap and small: Most modern satellites cost tens of millions of pounds, but going into space can cost less if scientists are prepared to think small and build 'smallsats'." New Scientist, 2016: https://www.newscientist.com/article/mg12216694-500-all-satellites-cheap-and-small-most-modern-satellites-cost-tens-of-millions-of-pounds-but-going-into-space-can-cost-less-if-scientists-are-prepared-to-think-small-and-build-smallsats/
[10] PlanetLabs, "Planet Labs", 2016: https://www.planet.com/about/.
[11] Terrabella, "Terrabella", 2016: https://terrabella.google.com/?s=about-us.
[12] E. Huet, "Google Buys Skybox Imaging - Not Just For Its Satellites", Forbes, 2014: http://www.forbes.com/sites/ellenhuet/2014/06/10/google-buys-skybox-imaging-not-just-for-its-satellites/#46fe595d425d.
[13] J. B. Campbell and R. H. Wynne, Introduction to Remote Sensing, Fifth Edition. Guilford Press, 2011.
[14] Satellogic, "Our Technology", 2016: http://www.satellogic.com/#!technology/c1w2a.
[15] W. Harwood, "NASA launches $855 million Landsat mission", 2013: http://www.cbsnews.com/news/nasa-launches-855-million-landsat-mission/.
[16] L. Valentini, "Google Earth – an introduction", 2011.
[17] M. K. Macauley and T. J. Brennan, Enforcing environmental regulation: Implications of remote sensing technology. Resources for the Future, 1998.
[18] M. Urban, "How many Russians are fighting in Ukraine?", BBC, 2015: http://www.bbc.co.uk/news/world-europe-31794523.
[19] UNOOSA, "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies", 2016: http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html.
[20] J. LaFleur, "Government, media focus on commercial satellite images", 2011: http://www.rcfp.org/browse-media-law-resources/news-media-law/news-media-and-law-summer-2003/government-media-focus-comm.
[21] R. Z. George and R. D. Kline, Intelligence and the National Security Strategist: Enduring Issues and Challenges. Rowman & Littlefield, 2006.
[22] Reuters, "New Turkish Satellite Could Publish Uncensored Images of Israel", Haaretz, 2011.
[23] D. Campbell, "US buys up all satellite war images", The Guardian, 2001.
[24] UNISPACE, "About the Charter", 2016: https://www.disasterscharter.org/web/guest/about-the-charter.
[25] UNOOSA, "United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER)", 2016: http://www.unoosa.org/oosa/ourwork/un-spider/.
[26] M. Franco, "15 space organizations join hunt for missing Malaysian jet", CNET, 2014: http://www.cnet.com/news/15-space-organizations-join-hunt-for-missing-malaysian-jet/.
[27] Faa.gov , "Satellite Navigation - GPS - Policy - Selective Availability", FAA, 2014: http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/gps/policy/availability/.
[28] E. Wax, "Mumbai Attackers Made Sophisticated Use of Technology", The Washington Post, 2008.
[29] Brustein, J, "GPS as We Know It Happened Because of Ronald Reagan", Bloomberg.com, 2014: http://www.bloomberg.com/news/articles/2014-12-04/gps-as-we-know-it-happened-because-of-ronald-reagan
[30] Florini, A, "No More Secrets?: Policy Implications of Commercial Remote Sensing Satellites" Carnegie Endowment for International Peace, 1999: http://carnegieendowment.org/1999/06/30/no-more-secrets-policy-implications-of-commercial-remote-sensing-satellites-pub-150