Remote Sensing Analysis for Arms Control and Disarmament Verification

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Overhead imagery can generally be divided into space-based satellite imagery, and aerial imagery from autonomous or non-autonomous vehicles, such as aircraft, drones, or even dirigibles. Since the early days of flight, humans have attempted to capture images from the sky. Aerial imagery played a critical role in World War II, where images collected by daring pilots at great risk helped identify German U-boats and detect Germany's development of the V1 flying bomb and V2 ballistic missile.

Satellite imagery was initially exclusive only to those who could afford to build satellites and launch them into space -- the United States and Soviet Union. Early remote sensing satellites like the CORONA system captured analog images on film, which had to be returned to Earth in capsules that were caught mid-air by airplanes. The capsules were sometimes lost, damaged, or the film was misprocessed. Printed images were large and kept rolled up like scrolls. While it is difficult to compare with today's digital images, the very first CORONA imagery was around ~12m resolution, and only panchromatic (black and white). Printed images were difficult to duplicate, share, and analyze. Measurements were taken with physical tools like a gerber scale. Errors, including very significant errors, were common. Furthermore, there were very few satellites orbiting the earth, meaning that coverage was episodic and tasking difficult.

Today there are 396 earth observation satellites orbiting Earth, as of August 2016 according to the Union of Concerned Scientists.[1] These satellites are owned by dozens of countries and private firms. A diversified market offers more choices for data. More images of the earth are taken today than ever before, making it more likely that an image will be available of a desired location at a desired time. More competition also means that the price of commercial imagery is coming down. At the same time, technological breakthroughs mean the quality of the image is increasing. Today, images are digital which makes it easier to share them, and we are only now beginning to understand the ways we can take measurements from them.

Types and Characteristics of Imagery:

Not all satellite imagery is equal. One of the measurements of quality is spatial resolution. How much physical space is captured in a single pixel? The gold standard in the open source is currently 31cm per pixel, which is available from DigitalGlobe's WorldView-3 and WorldView-4 satellites. Each pixel represents approximately $31cm^2$ of space depending on the topography of the location.

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[1] "UCS Satellite Database," Union of Concerned Scientists, August 11, 2016, http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.WMsMfvnytEY.

Another measurement is spectral resolution. How many bands of light wavelengths can be captured by the sensor? All satellites will be able to capture at least one band of light. Typically, commercial satellite companies sell 4 bands: red, green, blue, and near infrared (NIR). However, it is now possible to buy many more bands of light from companies like DigitalGlobe, and the US government's Landsat 8 satellite offers 11 bands.

Another important measurement is temporal resolution, sometimes called cadence or revisit rate. How frequently does the satellite orbit and capture the location one wants to monitor? One of the important disruptors of the imagery industry is the use of numerous smaller and cheaper satellites to collect imagery more frequently in a large constellation. An example of how useful this can be for monitoring and verification is an examination of Chinese-North Korean border traffic. High resolution images of sensitive locations can be useful. However, traffic is by nature a temporal activity. Jeffrey Lewis leveraged the lower spatial resolution, but higher temporal resolution of Planet imagery to respond to an assertion that cross-border traffic was decreasing and offered compelling evidence that indeed traffic was continuing as normal.

It is also important to consider the size of the footprint of that image, and the angle at which it is captured. An image looking "straight down," or 0° off nadir, captures only the rooftop of a skyscraper, but an image 10-25° off nadir may show you one or two walls of the building. You lose spatial resolution with a higher degree, and beyond 25° may be difficult for humans to interpret without comparison images or advanced analytics. Nonetheless, it is sometimes extremely useful to see the side of a building, particularly when matching windows on the outside to an image taken from the inside.

What we generally think of when we see imagery is electro-optical imagery, which we will just call optical imagery. This is essentially the Sun's light reflected off the Earth's surface and captured by a sensor on a satellite. Some of these wavelengths are visible to the human eye and some are not.[2] Panchromatic imagery is simply grayscale data, which is stored with a numeric value of intensity. Since it is a small amount of stored data it is also the highest "sharpness." It is often overlooked because "it is only black and white," but its benefit is often high spatial resolution.

The human eye can see red, green, and blue (RGB) wavelengths, so it is extremely common to process these three spectral bands of light into what is known as a "natural color" image. Because this multispectral image has more data per pixel, it is less sharp to the human eye. Today, it is common to "pan-sharpen" multispectral images by using a software or algorithm to process the panchromatic and/or NIR band to compromise between the "sharpness" of

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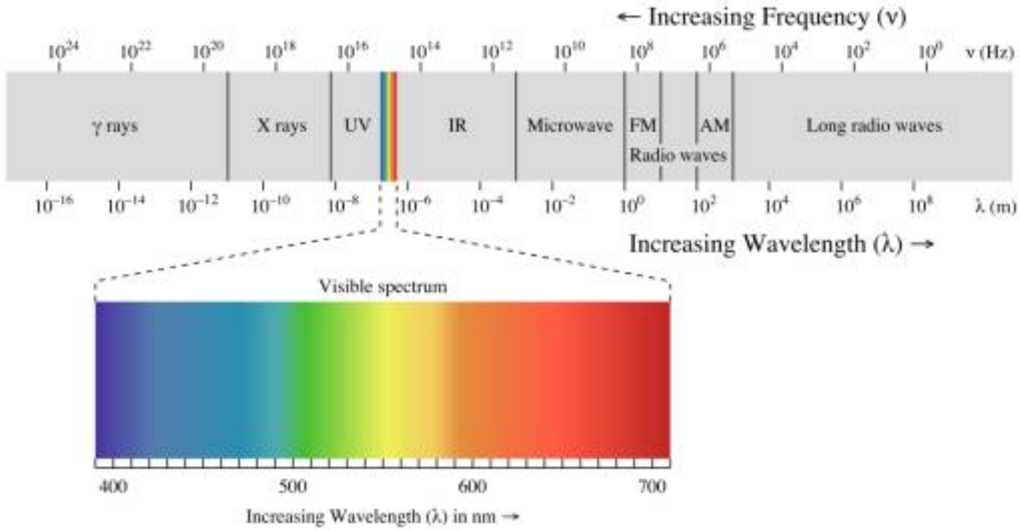
[2] A good primer on how light is collected by sensors and stored in digital form is here: http://go.hexagongeospatial.com/introremotesensing.

panchromatic imagery and the useful color information. Pan-sharpened multispectral imagery is what is displayed on mapping websites like Google Maps.



Source: Wikimedia Commons

In addition to light visible to the human eye, many civilian, commercial, and military satellites collect non-visible wavelengths of light. NIR light reflects well off of healthy vegetation, and can be used to detect camouflage vehicles or netting, as well as disruptions in healthy vegetation like burn scars from missile launches, or tracks created by heavy vehicles, or construction. Because NIR is not visible to the human eye, it must be "false-colored" with light that humans can see. Commonly the NIR data is turned red, red data is turned green, and green data is turned blue. This can give the appearance of a "reddish" image, where intense red represents healthy vegetation. One use-case was detecting two failed North Korean missile tests at Kusong Airbase in October 2016.[3]

Shortwave infrared imagery (SWIR) is also frequently offered in one or more bands. WorldView-3 offers 8 bands of SWIR data. One of the advantages of using SWIR data is that it is better at penetrating dense atmospheric conditions like water vapor or smoke. It's possible to see through smoke and identify the hotspots of a fire, for example. Because it has a distinct reflectance off of water, ice, and even some man-made materials reflect with a specific signature, SWIR data can be used to classify land for urban planning, and some mineral detection.[4] Nonproliferation use cases are sparse, but it could have a benefit in monitoring uranium mining

[3] Click through to see the imagery: Anna Fifield, "Did North Korea just test missiles capable of hitting the U.S.? Maybe," *The Washington Post*, October 26, 2016, https://www.washingtonpost.com/world/asia_pacific/did-north-korea-just-test-missiles-capable-of-hitting-the-us-maybe/2016/10/26/984e8a21-e6a7-4689-81e0-21d7d25c302f_story.html?utm_term=.44ea1f4474f6.

[4] Deke Young, "Use Cases for SWIR Imagery," *DigitalGlobe Blog*, October 29, 2015, http://blog.digitalglobe.com/technologies/use-cases-for-swir-imagery-taking-a-closer-look-part-2-of-2/.

in the near term before space-based hyperspectral sensors are established, and it may be useful in classifying industrial buildings at nuclear and missile sites in order to monitor for change.

Thermal infrared imagery (TI) is a panchromatic dataset that indicates temperature, where white is "hot" and black is "cold." Landsat 8 has two TI bands that can be used to discriminate the Earth's surface temperature from its atmospheric temperature. Using ground truth data, one can calibrate the brightness of the pixel to measure temperatures. The downside of these sensors is that they represent 100m spatial resolution. Catherine Dill used Landsat TI data to show that a Chinese gaseous diffusion facility near Jinkouhe was still operating or at least generating heat beyond the ambient temperature.[5] It remains challenging to find facilities that are large enough that they can be "seen" at this resolution.

Hyperspectral sensors exist on aerial vehicles, but it is challenging to put them into space because of the sheer amount of data that needs to be processed and downloaded back to earth. NASA's EO-1 had a Hyperion sensor that collected over 220 bands of light at a 30m spatial resolution while it was in orbit.[6] Much like traditional spectroscopy done on the ground, materials have distinct signatures that can be detected across many wavelengths and used like a fingerprint to identify materials. Aerial hyperspectral data is collected from commercial vehicles for use in agriculture, mining, and oil and gas industries. The US military also employs hyperspectral sensors on aerial vehicles. HyperCubes and Planetary Resources are two startup companies that are seeking to put hyperspectral sensors in space. Nonproliferation applications could be numerous. CNS is currently seeking funding with HyperCubes to use Hyperion data to test whether certain facilities have unique spectral signatures that can be used to identify them.

Video from space is also starting to come available in the commercial sector. After acquiring Google/Skybox satellites, Planet now has video sensors. Urthecast sells imagery from an HD camera on the International Space Station. Video can be useful for tracking vehicle movements, but much like a single satellite in orbit, you have to be lucky enough to be collecting video at a time when something (other than clouds) are moving. Video by its very nature is a collection of many many frames or still images. Video will be instrumental in building machine learning algorithms that can identify and detect various objects on the ground, because there will be many frames which are taken at slightly different angles in quick succession. Urthecast released video of vehicle traffic around the Imam Khomeini Space Station in Iran in 2016.[7] In conversation with Urthecast sales team, Melissa Hanham learned that the camera is installed on the Russian portion of the space station, and that they occasionally interceded on collections requests of Russian territory.

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[5] Catherine Dill, "The Jinkouhe Gaseous Diffusion Plant is Hot!," *Arms Control Wonk*, September 23, 2015, http://www.armscontrolwonk.com/archive/605445/the-jinkouhe-gaseous-diffusion-plant-is-hot/

[6] "Sensors - Hyperion," USGS, December 2013, 2011, https://eo1.usgs.gov/sensors/hyperion.

[7] "Video of Iran's Space Launch Facility Reveals Increased Activity," *Urthecast Blog*, March 16, 2016, https://blog.urthecast.com/updates/video-irans-space-launch-facility-reveals-increased-activity/.

Unlike electro-optical sensors that capture the Sun's light reflected off the surface of the earth, there are several useful sensors that use their own signal like Synthetic Aperture Radar (SAR) and LiDAR (Light Detection And Ranging). One obvious benefit is that analysts do not have to rely on the presence of sunlight. SAR can be used at night and penetrates clouds. SAR data is already used in a number of military applications including tracking submarine wakes and detecting tunnels. SAR is available from a handful of commercial operators, but it remains very expensive and largely out of the reach of NGOs.

CNS and Airbus are currently in negotiations for a gift of SAR imagery, and for continued gifts of SAR data on Geo4Nonpro.org. CNS and Allison Puccioni have proposed to explore using 24cm spatial resolution SAR data to monitor construction around the Shahrud missile site in Iran. SAR will be applied in three ways, (1) for change detection, (2) to monitor for road traffic and construction in non-paved areas, and (3) to see through fiberglass roofs of buildings. Similar research was done by Allison Puccioni for IHS Jane's at North Korea's Sohae site.[8] SAR data can also be used to monitor earthquakes, and Lawrence Livermore has explored using it to monitor for underground nuclear testing.[9] North Korea's Punggye-ri test site is covered in trees making it difficult to use SAR there, but it would be easy to use at sites like Novaya Zemlya. Furthermore SAR data could be very useful in detecting shipping particularily compared to AIS beacons.

LiDAR, or Light Detection And Ranging, is the use of laser light to measure the distance to a target. It is commonly used from aerial vehicles to create digital elevation models (DEMs) of the surface of the earth. DEMs are widely available at different levels of accuracy from public and commercial sources. They can be used for accurate modeling of the surface of nuclear test sites. Though not a LiDAR DEM, a 3D model of North Korea's nuclear test site at Punggye-ri was made by Jeffrey Lewis, Nate Taylor, and Grace Liu. In combination with seismic data, they were able to show the approximate size and shape of North Korea's test tunnels, that North Korea could continue testing in the mountain, even to the point of testing a thermonuclear weapon, and that they were likely modeling their test tunnels on US test tunnels.[10]

Sources of Imagery:
Remote sensing data is more abundant than ever before. Here are some free, medium, and full-price options.

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[8] Allison Puccioni, "Penetrating Vision: Radar Imagery Analysis Fills Intelligence Gaps," *Jane's Intelligence Review*, May 2016; Allison Puccioni, "Leaps and Bounds: North Korean Nuclear Programme Advances," *Jane's Intelligence Review*, May 2016.
[9] National Nuclear Security Administration, Lawrence Livermore National Laboratory, "Earth's Subsurface from Space," *Science and Technology Review*, April 2005, https://str.llnl.gov/str/April05/pdfs/04_05.pdf.
[10] Article forthcoming.

Mapping sites: Even amateur sleuths can find free imagery online at sites such as Google Earth Pro, Google Maps, Bing Maps, Yandex, Here, and Baidu.[11] Each mapping site has a purchase agreement with one or more satellite companies. They regularly, but not always frequently, update their imagery. Many sites also do not publish the date of their imagery. The desktop version of Google Earth Pro, which is now available for free, stands head and shoulders above the other sites, because it has historical imagery, with date, and a number of tools to measure and annotate objects. The new browser-based version of Google Earth remains useful for sharing data, and will in time receive some of the functionality of the destop version. Google has no plans to discontinue the desktop version of Google Earth and will continue to update imagery on it.

Each mapping site has to obey the laws of the jurisdiction in which it is incorporated. Some sites may choose or be required to blur or obstruct certain sites. A classic example is the NATO airbase at Volkel. Google and Bing chose to pixelate or black out the airbase, while Yandex does not obscure it.[12] These cases of censorship tend to draw attention more than anything else.

US Government Imagery: The US Government holds the largest cache of publicly available satellite imagery in the world. In addition, it hosts a number of digital elevation models, which allow for a topographical understanding of the surface of the earth. The Landsat missions have been imaging the earth since 1972, and the dataset is invaluable for measuring change over decades. Best of all it is free. Landsat 1 had a spatial resolution of ~80 meters and seven spectral bands. Landsat 8 now has a spatial resolution of 15m and 11 spectral bands.[13] While the sensors have improved, it is still a far cry from the high resolution imagery we are used to seeing on mapping sites. Typically, these images are best coupled with high resolution images, or used in aggregate to measure change over time. The low resolution means that only very large man-made objects are visible. Landsat missions have a broad array of spectral sensors that collect both visible and non-visible light, as described above.

Declassified imagery: Imagery batches declassified in 1996, 2002, and 2013 offer insight into US national intelligence thinking and historical information from selected sites. These images generally run around $30 USD each and take several days to weeks to receive.

Commercial imagery: High resolution imagery vendors such as Digital Globe and Airbus have large catalogs of imagery and digital elevation models available online, which are relatively easy to search. Other satellite companies in Korea, India, and Israel may require a more complicated

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[11] Melissa Hanham, "There's a Map for That," *Arms Control Wonk*, April 8, 2015, http://www.armscontrolwonk.com/archive/605116/theres-a-map-for-that-2/.

[12] Jeffrey Lewis, "Security Lapse at Volkel," March 24, 2014, http://www.armscontrolwonk.com/archive/207120/volkel/.

[13] "Landsat 1 History," USGS, https://landsat.usgs.gov/landsat-1-history; "Landsat 8 History," USGS, https://landsat.usgs.gov/landsat-8.

purchase arrangement through a sales office or third party vendor. Nearly all commercial vendors offer panchromatic, red, green, and blue bands of light, but many offer non-visible light bands as well. The commercial satellite with the highest resolution imagery currently in service is WorldView-4 at 30cm.[14] Several companies also offer satellite tasking as a commercial option, meaning that they will actually change the orbit of the satellite to capture specific images. The most affordable of these options is an Israeli company known as ImageSat International, which will capture 70cm panchromatic imagery for about $13.50 per km^2 with a 50 km^2 minimum order. ImageSat was also the first company to offer high resolution night imagery, which can be useful for identifying and monitoring security perimeters or covert construction, which are generally well lit at night.

Medium resolution imagery is increasingly popular. Planet recently acquired Google's Terra Bella satellites known previously as Skybox, along with RapidEye satellites. It now has the world's largest constellation of satellites. It is currently (and temporarily) offering access to its Beta version imagery search tool. The great benefit of this imagery is that while it doesn't have as high a spatial resolution as DigitalGlobe or Airbus imagery, it has a much higher temporal resolution -- or revisit rate. This means analysts are much more likely to get an image of the location they want at the time they want. Planet is approaching imaging the entire earth every day. As they continue to launch satellites into space, we will soon reach truly ubiquitous sensing. A competitor, BlackSky, is seeking to do the same thing. They are late to the game, but they are trying a new angle by combining geolocated social media feeds with satellite imagery.

Satellite images, like airline tickets, never have one price. Some companies like DigitalGlobe, will offer imagery grants to military and civilian academic institutions. The US government, as the largest purchaser of commercial imagery, gets a special rate from DigitalGlobe and Airbus. Imagery for publication or commercial use will be more expensive, and the price depends on the company, quality of the sensor, number of bands, surface area, and how recent it is. 31cm resolution 4-band WorldView-3 imagery sold less than 90 days after the image was taken and used for commercial purposes will cost about $27.50 per km^2, with a 25km^2 minimum order. 1.5m resolution 4-band Spot 6 imagery for commercial use will be $4.00 per km^2, with a minimum order of 100km^2.

Without image processing software and knowledge, it is generally best to purchase the imagery from a 3rd party re-seller, who can process the imagery for the end-user at an additional cost. Raw imagery will not reflect accurate colors or sharpness. Processing can include:

- color balance, which includes manually or automatically adjusting the red, green, and blue data to reflect accurate colors;
- pan-sharpening, which uses an algorithm to merge the panchromatic (black-and white) band for sharpness with the colors of the less-sharp red, green, and blue bands;

[14] "WorldView-4," DigitalGlobe, http://worldview4.digitalglobe.com/#/main.

- Mosaicing, which is tiling together several satellite strips to form one “seamless” image; and
- orthorectifying imagery, which layers many images from different days over a 3 dimensional elevation profile so as to line up all the significant objects on the image.

While many companies will offer these services for their own products, they will generally not orthorectify their imagery to another’s sensors, meaning a 3rd party re-seller or a skilled in-house image processor is needed. As a rule, it is better for analysts to be able to process their own imagery, because they most likely notice small details that an expert without domain knowledge would miss. It is extremely rare to find these individuals, however.

Common software for image processing includes, QGIS, ArcGIS, ERDAS Imagine, ENVI, PCI, and Photoshop. QGIS is open source, but focuses primarily on the GIS rather than image processing features. All the other software have varying price points which depend on usage (educational v. commercial), and number of site license. CNS purchased a single floating license for ENVI for $6,000, not including travel for training, and has access to ArcGIS and ERDAS Imagine through Middlebury.

Commercial aerial vehicle imagery is increasingly available for both commercial and nonprofit use; however it remains expensive. SkyTruth has harnessed aerial vehicles in order to monitor environmental issues, illegal fishing, and human trafficking. The challenge with aerial vehicles remains one of sovereignty. A state has to allow the vehicle in their airspace.

The Open Source Community:
In recent years, a number of institutions have begun to integrate satellite imagery into their research. Yet despite the bounty of data, groups exploiting it are relatively few in number, and many focus largely on optical images. A decent proxy for capacity is whether a group has a license for ENVI or other software to process an image in-house, or whether it must rely on others to process the image and works only in the visual space. Many groups can draw intelligent conclusions from visually examining images processed by others, but the ability to do in-house processing beyond the visual band offers significant advantages and is a useful distinction between low and high-capacity organizations.

Organizations working in this area include:
- 38 North, in partnership with Joseph S. Bermudez of Allsource Analysis
- Arms Control Wonk
- Bellingcat and the Atlantic Council’s Digital Forensic Research Lab
- Center for Strategic and International Studies
- IHS Markit (Jane’s)
- Institute for Science and International Security

- James Martin Center for Nonproliferation Studies (CNS), Middlebury Institute of International Studies at Monterey
- Project Alpha, King's College London
- Verification Research, Training and Information Centre (VERTIC)

In addition to these groups, it is worth noting that the IAEA and CTBTO are both international organizations that see value in working in this space. The IAEA has an in-house capacity to use satellite imagery. CNS, along with other institutions, has worked with the IAEA to build capacity in this area, although the IAEA remains limited by funding constraints. The CTBTO has a more restrictive mandate but is currently exploring how to build capacity in this area as part of on-site inspection.

The Future for Commercial Overhead Imagery:
The price of satellite images has dropped substantially, as launch costs decrease and smaller satellites are increasingly capable. Further decreases in price are likely a result of competition and lower costs. Competition comes in the form of not merely additional providers, but alternate business models that may fragment the market. These models include firms like Planet that trade spatial resolution for temporal resolution, as well as providers selling non-optical imagery. Government are still the main customers of commercial remote sensing data, however industry, agriculture, media, international organizations, and NGOs are starting to become larger consumers.

The most important change has been the development of what might be called "ubiquitous sensing." Miniaturization in microelectronics has allowed a significant reduction in the cost of satellites and their mass – reducing launch costs. This has enabled commercial providers that collect medium-resolution imagery comparable to what spy satellites collected a decade ago, but also totally new business models including moderate spatial resolution satellites with very high revisit rates. The best example of this is Planet, which is on course to take an image of the entire earth every day by 2018.

The same technological trends that had allowed new commercial entrants into electro-optical imaging have also opened up other kinds of sensors. There are new private firms to provide from space video, synthetic aperture radar, and hyperspectral images. Many of these sensors are extremely expensive at the moment, but the cost is expected to fall in the future. The most interesting development, from our perspective, are several firms attempting to build a constellation of satellite with hyperspectral sensors that provide far more data about objects than simple visual images.

The development of space-based hyperspectral sensors has been slowed by the very large data sets such sensors produce, which are a challenge for satellites to store and transmit. To date, this has largely confined hyperspectral senses to aircraft or very low-resolution satellites. Advances in data storage may make a number of new sensors more affordable in the future.

A major limitation on the adaptation of the arms control and disarmament community is a lack of human capital. One bottleneck is the tendency of our graduate schools to recruit students from political science and international relations programs instead of geographers and computer scientists. Young professionals largely lack the background to make a contribution in these new areas, since few graduate programs teach these tools. Moreover, few institutions maintain the capacity in the form of training, software licenses and computing power necessary to do more than look at pictures processed by other people.

The combination of the human capital bottleneck and massive influx of data means that there is a real lost opportunity. Solutions to the lack of human capital include crowdsourcing and machine learning.

There is a growing body of evidence that suggests crowds are as good as experts for a number of tasks. Wikipedia is a good example of the sort of information that can be curated by crowds. Studies have shown Wikipedia is, on average, as accurate as more traditional encyclopedias. CNS has undertaken a study to see whether the crowd can perform many tasks associated with analyzing visual satellite images. This experiment is currently being conducted on a website called Geo4Nonpro.org that allows a selected group of people to look at satellite images of sensitive locations and pin areas of interest.

Another major development relates to machine-learning and automation in analyzing satellite images. A number of groups are already building algorithms for object recognition, change detection and pattern of life mapping. For example, a team from Carnegie Mellon University created Terrapattern, a visual search tool for satellite imagery. Terrapattern is a simple proof of concept that allows users to select a tile in a satellite image of the city – with, say, a tennis court – and it will return similar tiles, providing an initial list of all the tennis courts in San Francisco.[15] Companies like Google, Orbital Insight, Kitware, and others are also moving into this space. These tools are becoming increasingly important as the amount of imagery increases, both in terms of the number of providers but also the cadence (temporal resolution) of providers like Planet. As firms like Planet move to daily, or even sub-daily, imaging of the earth, automated change detection, object recognition, and search capabilities are essential tools to process the large amounts of data.

Masking Proliferation from Remote Sensing:

[15] See: http://www.terrapattern.com/

Remote sensing is not new, and there have been many ways that states have avoided detection from sensors. The largest difference today is that there are more sensors than ever before. As we enter an era of ubiquitous sensing, states may return to some old and new techniques to evade or disrupt detection. An example of deception dating back to the late 18th century is the Potemkin village. Today, states still attempt to use decoys and "confusers" like inflatable aircraft and missile transporter erector launchers demonstrated in Russia in 2016.[16] These decoys won't stand up to hyperspectral imagery, which can detect material. However, it will drive up the cost of remote sensing by forcing states into more expensive imagery. Similarly, states still use camouflage, but they are updating it for the satellite age by making it blockier and pixelated. This is largely because they are no longer hiding these vehicles from binoculars, but from satellites.[17]

Also not new is the idea of moving illicit activities underground. A key example is Syria's effort to disguise a plutonium production reactor near al-Kibar as a byzantine fortress.[18] This type of disguise is not foolproof, but again increases the cost of remote sensing.

Another tactic that has been employed with great success is simply to flood media with false or confusing imagery. In a charged political environment, it may not matter if there is "proof" in a satellite image if another image can be offered with "alternative facts." If enough people want to believe the alternative information, it may no longer matter. To the extent possible, it is important for institutions and media to remain unaffiliated with a particular political narrative, and to detect and out any use of doctored images. CNS researchers used the photo interpretation software Tungstene to detect doctored satellite images during the international investigation of flight MH17.[19]

Increasingly, there is a concern about the use of cyber (or even kinetic attacks) on satellites, their downlinks, or their data stores. There has yet to be a public report of such an attack on commercial satellites, but it is something to look for in the future.

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[16] Andrew Kramer, "A New Weapon in Russia's Arsenal, and It's Inflatable," *The New York Times*, October 12, 2016, https://www.nytimes.com/2016/10/13/world/europe/russia-decoy-weapon.html?_r=0.
[17] Jack Stewart, "The Story Behind China's 'Minecraft' Military Camo," BBC, March 24, 2016, http://www.bbc.com/autos/story/20160324-the-story-behind-chinas-minecraft-military-camo.
[18] "Al-Kibar Facility Page," Nuclear Threat Initiative, March 1, 2011, http://www.nti.org/learn/facilities/461/.
[19] Catherine Dill, Jeffrey Lewis, Melissa Hanham, David Schmerler, "MH17 Anniversary," *Arms Control Wonk,* July 15, 2016, http://www.armscontrolwonk.com/archive/1201635/mh17-anniversary/.