SPACE AGE SURVEILLANCE

AND ITS IMPACT ON DEFENCE INTELLIGENCE

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PRIVATE and public investment in space-based assets has sky-rocketed over the last decade, with the explosion in enterprises spawning a new extraterrestrial expression. 'Astropolitics'[1] – which refers to the projection of international commercial, political and military power in space – is, however, merely a modern moniker for a competition that began in earnest during the Cold War. The American and Russian space race was hard fought but fruitful, propelling to maturity the technologies that made the International Space Station and the US' global positioning system possible.

One major difference between the past and present is the number of runners competing. Today, two have become 'many' with Elon Musk's Space-X programme, the revving up of a joint Toyota-Japanese space agency lunar rover and the proliferation of high-tech satellite launches by private providers, to include Planet and Black Sky.[2] The pace is picking up developmental momentum with advances in satellite Earth observation technologies.

For those in the business of security and defence, this is an exciting era. Recent evolutions in the tech on-board orbiting satellites are making intelligence, surveillance and reconnaissance capabilities almost ubiquitous. Indeed, near-Earth and outer-orbit constellations, with satellites ranging from Rubik's-sized 'CubeSats' to 2,800kg, bus-sized behemoths carrying hyper-spectral and synthetic aperture radar sensors, are everywhere.[3] The sheer number of satellites in orbit and the advanced observation functionalities they are equipped with can benefit everything from an Atomic Energy Agency nuclear inspection in North Korea to military unmanned aerial system missions. Satellite Earth observation is changing the security space game.

GAME-CHANGING SENSORS

Earth observation instruments aboard new-generation satellites are turning out powerful intelligence, surveillance and reconnaissance products for commercial, civil government and military organisations. In early 2000 there was only one satellite in orbit equipped with the electro-optical sensors capable of sampling distances of two metres or less. By 2015, that number

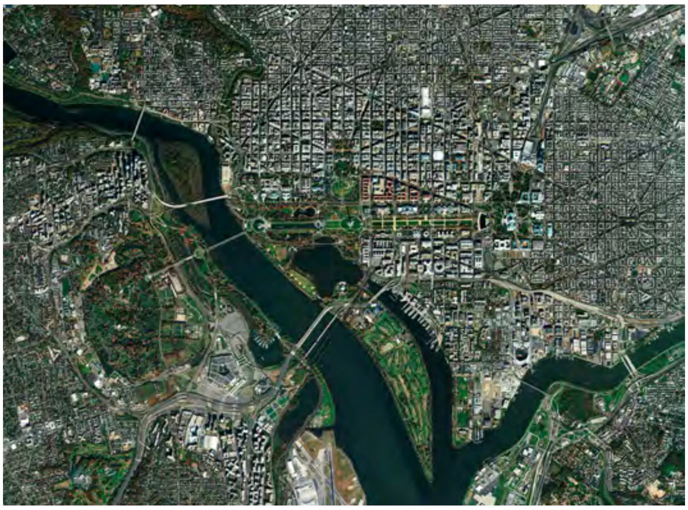
[1] First coined by Dr. Everett Dolman in his 'Astropolitik.' He, Qisong "China-Russia Technology Cooperation in Space: Mutually Needed or Mutually Exclusive?" Pacific review 36, no. 4 (2023): 897–926.

[2] edition.cnn.com/2019/03/13/business/toyota-moon-rover-japan/index.html

[3] These are commonly referred to as 'Nanosats' and 'CubeSats.' See euroconsult-ec.com/press-release/one-ton-of-smallsats-to-be-launched-per-day-on-average-over-the-next-decade-yet-challenges-remain

had jumped to nearly 30. Today companies are operating their own 30-plus-strong constellations and these numbers are expected to rise, with around 1,000 launches recorded in 2020 alone.[4]

Developments have primarily been focused on upgrading the passive and active sensors aboard these satellites. The former group, which includes radiometers and spectrometers, generate high-quality, true-colour images by observing electromagnetic radiation reflected from the Earth's surface. By picking up this electromagnetic energy in the visible, infrared, thermal infrared and microwave spectrum, they produce multi-layered, quality-corrected pictures that cover large swathes of the Earth's surface. These images are becoming increasingly common features of news reports and policy documents. Alongside passive sensors and passive sensor pictures are active sensors and their data contributions. Active sensors enable the capture of high-quality, false colour composite images. They consist of radio and ranging (radar) sensors, such as altimeters and scatterometers, that send and receive microwave energy to and from the Earth's surface. This data generates synthetic imagery products for visual presentation.



"EARTH OBSERVATION SATELLITES MAY HAVE BEEN IN ORBIT SINCE SPUTNIK-1 BUT THOSE BEING LAUNCHED TODAY ARE BY COMPARISON 'OUT OF THIS WORLD' THANKS TO THE HIGHER-RESOLUTION DATA THEY PROVIDE."

Earth observation satellites may have been in orbit since Sputnik-1 but the satellites being launched today are by comparison 'game changers' thanks to the spatially, spectrally, radiometrically and temporally higher-resolution data they supply. Hyperspectral, synthetic aperture radar and near-real-time observation frequency are all part of a tech cohort jointly considered under the umbrella of 'high-resolution' advancements. The resolution considered in satellite sensor data differs from the resolution considered for the Apple iPhone lens. Satellite sensors have spatial, spectral, radiometric and temporal resolution grades that impact their utility as intelligence, surveillance and reconnaissance assets.

- Spatial resolution refers to pixel size (how many pixels an image has) and the geographic space represented within a single pixel. This is the resolution considered for the common camera lens.

- Spectral resolution refers to how many different spectral channels a given sensor package can capture.[5]

- Radiometric resolution refers to how well a sensor picks up on slight variations in received electromagnetic energy.

- Temporal resolution refers to the time lapse between observations – how long it takes one sensor to complete a full orbit and observe data at the same point. High temporal resolution directly equates to improved change detection analysis and near-real-time decision making power. For example, consistent satellite coverage over one geographic coordinate enables more precise record keeping of rapid changes in lines of control.

So how are enhancements of these sensors changing the role of satellite data in intelligence, surveillance and reconnaissance? Primarily by providing civil government and the military with readily accessible, high-resolution repositories that can be used in myriad applications alongside – and in tandem with – other intelligence assets. When coupled with machine learning and complementary sensor products, this data can generate insightful, policy-changing pictures. High-resolution archival satellite data repositories provide almost unrestricted accessibility to otherwise restricted and/or hard to reach spaces. Satellites have already been at work subverting the "spectacle of secret spaces," the concept of government-restricted and unseen sites where military and security activities are conducted in private.[6] A recent example of satellite data supplying otherwise publicly unobtainable information that directly informed US government decision making is the Chinese spy balloon incident. Although the balloon launch site, day of release and initial flight pattern were not publicly disclosed or known, high-resolution satellite imagery made it so. By referencing relevant imagery corresponding to the geographic and temporal location of the balloon, analysts were able to determine its flight speed, travel path, launch site and day of departure. The imagery confirmed military intelligence of the balloon's whereabouts post-launch and also provided undeniable and unclassified evidence. Thus, on top of providing valuable, if redundant, information to the military, it provided shareable evidence that subsequently influenced public policy.[7]

High-resolution sensor data, in fusion with machine learning, is also opening the door to new applications. High-resolution imagery, when compiled with web-mapping models, convolutional neural networks and other resources, exhibits a form of data fusion that leads to insight. For example, to respond to global positioning system 'spoofing' attacks on unmanned aerial vehicles, satellite imagery promises an independent positioning, navigation and timing capability. DeepSIM is a proposed spoofing detection model that uses machine learning techniques to cross-analyse archival satellite imagery and on-board aerial imagery to identify incongruent global positioning system signals within less than 100 milliseconds.[8] Another example of satellite imagery being used in collaboration with artificial

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[4] *astronomy.com/space-exploration/how-many-satellites-are-orbiting-earth*

[5] *This is where the terms multispectral and hyperspectral come into play.*

[6] *Perkins, Chris, and Martin Dodge. "Satellite Imagery and the Spectacle of Secret Spaces." Geoforum 40, no. 4 (2009): 546–560.*

[7] *Pabian, Frank. "Commercial Satellite Imagery as an Evolving Open-Source Verification Technology: Emerging Trends and Theiri Mpact for Nuclear Nonproliferation Analysis" 27687 (2015).*

[8] *Xue, Nian, Liang Niu, Xianbin Hong, Zhen Li, Larissa Hoffaeller, and Christina Pöpper. "DeepSIM: GPS Spoofing Detection on UAVs Using Satellite Imagery Matching" In ACM International Conference Proceeding Series, 304–319, 2020.*

intelligence is the tracking of Chinese ships across the Atlantic, which uses a very similar model.

High-resolution satellite sensor data is also in high demand for use in longitudinal change-detection modelling and studies. For change detection modelling, two or more images with the same projection centre are compiled and their different values calculated and projected in a like-image. Although human change detection via the physical notation of geotemporal changes between any given set of images is commonly used in scouting missions, artificial intelligence applications are becoming more common with the advent of technological advances in sensor data. This is also how the US and allies have assessed uranium ore processing at North Korea's nuclear facilities.

Change detection via artificial intelligence is conducted by assessing two or more imagery sets/stacks and calculating the difference between their electromagnetic values and displaying those differential values on another image. A recent example of this process providing crucial intelligence, surveillance and reconnaissance capabilities is NASA's estimation of Ukrainian harvest profits obtained by Russia in occupied territories. NASA Harvest, which is focused on agricultural monitoring and production forecasting from the local shareholder to international level, uses synthetic aperture radar and optical data – at 20 metre spatial resolution – obtained from the US Geological Survey-owned satellites Sentinel-1, -2 and Landsat-8.

HOW SHOULD THE TECHNOLOGIES BE USED?

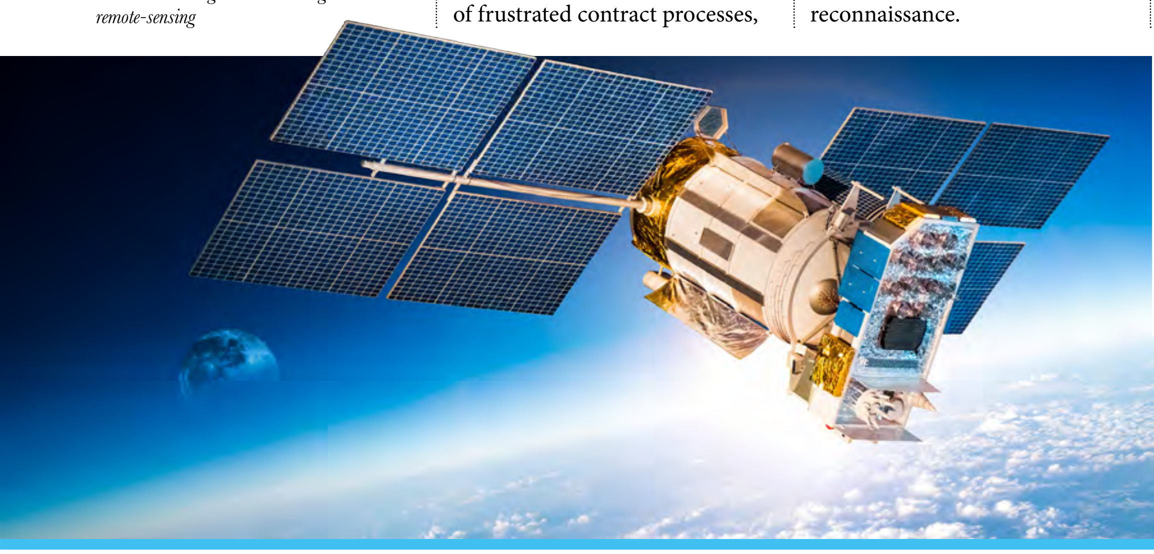
Satellite remote sensing data provides valuable insights for "data-informed decision making based on the current and future state of our planet."[9] Data-informed insights are advantageous to the commercial, civil government and military sectors. UN population displacement estimates, US forest fire management, Atomic Energy Agency nuclear non-proliferation monitoring and allied ship identification efforts all benefit from high-resolution Earth observation data. With new and recent announcements of future satellite sensors capable of obtaining 0.5 metre resolutions at quicker near-real-time revisiting rates, future technological advances are expected, but must be properly understood.

Thus, it seems the biggest barrier to the armed forces using everything space-based satellite assets hold is the ever-present and almost accepted discrepancy between military and commercial/civilian cooperation. As a consequence of frustrated contract processes, which sometimes do not provide appropriate levels of flexibility and renewals, and the operational differences between camps, collaboration is often problematic and not easy to overcome. Even though this is an issue that is routinely voiced, little progress seems to be made.

THE NEXT CHAPTER

Fully exploiting satellite visual sensor data for state security and military interests will require and reward competitive investment. Investing and exploiting these technologies is going to be the biggest challenge for militaries and their governments moving forwards. With the commercial industry making strides in space, and considering long-standing issues between government and commercial integration, these new Earth observation instruments – and the data they produce – may be at risk of under-utilisation. Governments must weigh up the financial and temporal pros and cons of investing in their own manned constellations of satellites whilst also collaborating with private sector contractors to do the same, and harnessing the innovation and expertise that would bring to bear. Despite the inherent differences and non-conformity of private and government sectors, cooperation must happen and must happen fast if Western allies are to remain among the front-runners in the field of intelligence, surveillance and reconnaissance.

[9] *earthdata.nasa.gov/learn/backgrounders/remote-sensing*



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