collaborate. "Rubens comes in and does some figures, and then Jan Breughel comes in and does the horses, the dog and the lion, because he's 'Mister Animal'," Honig says. "And so they fit the things together."

Many art historians surmised, on the basis of records and close observation, that this is what happened with numerous paintings by the younger Brueghels. The computer helps to prove it. Hong says: "It addresses a lot of questions about the process of production."

The computer scientists bring their own questions to the project. To them, Honig's collection is a perfect data set with which to stretch their algorithms. Working with paintings challenges a program's pattern-matching capacity, says Mathieu Aubry, a specialist in computer vision and deep learning at École des Ponts ParisTech in France. The difficulty hinges on differences in media and colour. Computer vision can't, he explains, "recognize that a house is the same in a drawing and an oil painting if it has not been trained to do so". The sharp linearity of draughtsmanship and relatively blurred edges in oil painting can confound algorithms.

It would take too long to annotate identical objects or teach the computer to look for certain similarities, such as shape. So Aubry and his colleagues used a technique called unsupervised deep learning, in which the algorithm is shown the pictures and finds similarities for itself. The results could feed into more practical applications of AI vision, he says, such as self-driving cars.

His team posted the results — for instance, a cannon and a chandelier both repeated across five separate pictures — on the arXiv preprint server in March (X. Shen *et al.* Preprint at https://arxiv.org/abs/1903.02678; 2019). And next week, they will present them at the 2019 Conference on Computer Vision and Pattern Recognition in Long Beach, California. Although unsupervised deep learning typically takes a lot of computer power, Aubry says, it is mostly immune from human preconceptions. So it's a good way to avoid biases such as the tendency to focus on the main features of a picture.

"AI allows art history to be treated, for the first time, as a predictive science.""

TELLING TRENDS

Similar technology is being used at Rutgers University in Piscataway, New Jersey, to map how style is defined and develops over time in artists as diverse as Rembrandt van Rijn and the Russian avant-garde artist Kazimir Malevich. "We had theories but they're not provable," says art historian Marian Mazzone, a member of the Rutgers Art and Artificial Intelligence Laboratory. "Computer science may be a tool that can help me empirically answer some of these questions."

Working with lab head Ahmed Elgammal, she has produced a digital analysis of 77,000 of works of art spanning five centuries, from the Renaissance to pop art (A. Elgammal *et al.* Preprint at https://arxiv.org/abs/1801.07729; 2018). To the team's astonishment, the computer — also using unsupervised learning — put the artworks into chronological order.

The project confirmed a theory of eminent twentieth-century art historian Heinrich Wolffin. He argued that shifts in artistic style could be analysed and categorized according to five binary characteristics. One was whether the work was 'linear' (contour-led, as in the work of Sandro Botticelli) or 'painterly' (reliant more on brushstrokes denoting light and shadow, as in the paintings of Tintoretto). Elgammal argues that AI allows art history to be treated, for the first time, as a predictive science that compares theory with observations.

Elsewhere, AI is being harnessed to address a perennial problem of material legacy that underpins art history: deterioration. For instance, the Verus Art system from start-up Arius Technology in Vancouver, Canada, is deploying a 3D scan–print system — initially devised to study damage to Leonardo da Vinci's *Mona Lisa* — to replicate artworks precisely, down to textured brushstrokes and pigment hues. Intended for education, outreach and archives, the 'backed-up' paintings might have another use: foiling thieves more discerning than those fooled by Castelnuovo Magra's cheap copy. ■

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MILITARY TECHNOLOGY

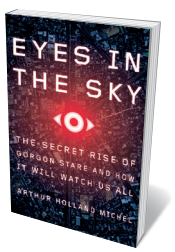
Eyed up: the state of surveillance

Sharon Weinberger is struck by a book on a technology aimed at capturing everyone's every move.

In the 1998 Hollywood thriller *Enemy of the State*, an innocent man (played by Will Smith) is pursued by a rogue spy agency that uses the advanced satellite "Big Daddy" to monitor his every move. The film — released 15 years before Edward Snowden blew the whistle on a global surveillance complex — has achieved a cult following.

It was, however, much more than just prescient: it was also an inspiration, even a blueprint, for one of the most powerful surveillance technologies ever created. So contends technology writer and researcher Arthur Holland Michel in his compelling book *Eyes in the Sky*. He notes that a researcher (unnamed) at the Lawrence Livermore National Laboratory in California who saw the movie at its debut decided to "explore — theoretically, at first — how emerging digital-imaging technology could be affixed to a satellite" to craft something like Big Daddy, despite the "nightmare scenario" it unleashes in the film. Holland Michel repeatedly notes this contradiction between military scientists' good intentions and a technology based on a dystopian Hollywood plot.

He traces the development of that technology, called wide-area motion imagery (WAMI, pronounced 'whammy'), by the US military from 2001. A camera on steroids, WAMI can capture images of large areas, in some cases an entire city. The technology got its big break after 2003, in the chaotic period following the US-led invasion of Iraq, where home-made bombs — improvised explosive devices (IEDs) — became the leading killer of US and coalition troops. Defence officials began to call for a Manhattan Project to spot and tackle the devices.



Eyes in the Sky: The Secret Rise of Gorgon Stare and How It Will Watch Us All
ARTHUR HOLLAND MICHEL
Houghton Mifflin Harcourt (2019)

In 2006, the cinematically inspired research was picked

A1C AARON MONTOYA/PLANET PIX VIA ZUMA

The camera of an MQ-9 Reaper drone, used for surveillance by the US Air Force.

up by DARPA, the Defense Advanced Research Projects Agency, which is tasked with US military innovation (D. Kaiser *Nature* **543**, 176–177; 2017). DARPA funded the building of an aircraft-mounted camera with a capacity of almost two billion pixels. The Air Force had dubbed the project Gorgon Stare, after the monsters of penetrating gaze from classical Greek mythology, whose horrifying appearance turned observers to stone. (DARPA called its programme Argus, after another mythical creature: a giant with 100 eyes.)

Some books use blockbuster action films to demonstrate — or exaggerate — a technology's terrifying potential. Here, *Enemy of the State* shows up repeatedly because it is integral to the development of Gorgon Stare. Researchers play clips from it in their briefings; they compare their technology to Big Daddy (although their camera is so far only on aircraft, not a satellite). At one point, incredibly, they consult the company responsible for the movie's aerial filming. (It set me wondering — which government lab out there is currently building the Death Star from Stars Wars?)

Holland Michel's book is not the first to look at technologies intended to achieve omniscience, but it is among the best. Writers examining the intersection of technology and privacy often repeat well-worn tropes, claiming that every novelty is the new Big Brother. But *Eyes in the Sky* is that rare creature: a deeply reported and deftly written investigation that seeks to understand both the implications of a technology and the motivations of its creators. Holland Michel notes tensions between security and privacy without hyping them.

And he gets those responsible for building WAMI to speak to him candidly — sometimes shockingly so. Take, for example, the former US military officer who touts the 'benefits' of the colonial subjugation of India (which he bizarrely claims created order among the country's ethnic groups) to justify mass surveillance in the United States.

This potential for domestic mass surveillance becomes a key point. As the story proceeds, WAMI's creators start looking for ways to use the battlefield technology at home: having built a new hammer, they search for more nails. Here, the story takes an even more dystopian turn. John Arnold, "a media-shy billionaire", uses his own money to help secretly deploy a WAMI system to assist the police in tracking suspects in crime-ridden Baltimore, Maryland. Arnold, who has funded other "new crime-fighting technologies", first learnt about WAMI's use overseas from a podcast, and decided to debut it stateside. "Even the mayor was kept in the dark," Holland Michel writes.

PRIVATE INTERESTS

Is this our future? A world in which billionaires fund the police to record entire cities from above? That plot twist is less *Enemy of the State* than *Batman*, although it's hard to know who the hero is. (At least the fictional Big Daddy was funded by Congress, even if its supporters had to kill one stubborn lawmaker to get the job done.) It's enough to make us all reach for tinfoil hats, which could come in handy to block what Holland Michel warns is coming next: infrared imaging that can detect people inside their homes. WAMI, if deployed above your city, already has the capacity to track your daily commute and errands, and allow those watching to retrace your steps for days or weeks.

To his credit, Holland Michel's interviews with surveillance technologists are reported with context but without commentary, allowing readers to draw their own conclusions. In one understated episode, he reveals that — after the Baltimore project was exposed — the owner of the company that built and deployed the WAMI system there had "personally" provided gifts to a community organizer. The organizer was working to convince Baltimore residents that a skyborne Big Brother might be in their interests.

One unanswered, and perhaps unanswerable, question is how successful WAMI was at its original purpose: preventing insurgent bomb attacks in Iraq and Afghanistan. Holland Michel isn't sure, because the answer is classified. Although investment in WAMI is "furious and ongoing", he notes, "the Air Force declined repeated requests for even an approximate indication of WAMI's impact on the battlefield".

What we do know is that Afghanistan, one of the most surveilled countries on Earth, is slipping further into chaos. That can't be blamed on WAMI, but it does indicate that the tech is not today's Manhattan Project.

There are other questions. By focusing on a specific technology, does Holland Michel miss a bigger picture? Is the more serious threat the access of governments and corporations to our electronic devices? The answer to both is no, because he also traces how meshing WAMI with other sensors, including those on smartphones, will eventually create "a fully fused city" where "there may be nowhere to hide". In the end, *Eyes in the Sky* transcends its title by using Gorgon Stare as a window into our future. And that is bleak.

When Gorgon Stare is completed, Michael Meermans, an executive at Sierra Nevada (the company in Sparks, Nevada, that built it) asks himself rhetorically whether the task is over. Of course not. "When it comes to the world of actually collecting information and creating knowledge," Meermans says, "you can never stop." ■

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CORRECTION

The book review 'The long, strange trip of mescaline' (*Nature* **569**, 485–486; 2019) misstated Frederick Smith's role: he was head of the Reorganized Church of Jesus Christ of Latter-Day Saints, now known as the Community of Christ.