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News & Highlights

Cold War Satellite Imagery Gets New Life

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The weather was clear over the northwestern Soviet Union on 16 September 1967, offering excellent photographic conditions for the US spy satellite passing overhead. Part of a top secret program known as Corona, the satellite shot a strip of film and continued its orbit. Whether those particular images provided any important Cold War intelligence is unknown, but more than 50 years later, they have proven crucial for Volker Radeloff, a professor of forest and wildlife ecology at the University of Wisconsin–Madison, who studies how land use patterns change over time.

The area the satellite photographed now straddles the border between Russia and the Eastern European country of Latvia, and Radeloff and his colleagues wanted to understand why the forest in this region has been expanding. Researchers had assumed that trees began to regrow after the Soviet Union collapsed in 1991. But as Radeloff and his colleagues revealed in 2020 [1], the reforestation was underway in the 1960s. The scientists had access to other satellite imagery from the 1980s, but the Corona photographs allowed them to look deeper into the past. "Being able to go back another 20 years is big," said Radeloff.

More than 100 Corona satellites circled the Earth from 1960 to 1972, snapping over 860 000 high-resolution photographs of much of its land surface [2,3]. Researchers began analyzing the photographs shortly after the first ones were declassified in 1995, and they have already used the images to triple the number of known archaeological sites in the Middle East [4], document the shrinkage of glaciers in central Asia [5], track declines in rodent populations on the steppes of Kazakhstan [6], and perform numerous other studies. Jason Ur, professor of archaeology and ethnology at Harvard University in Cambridge, MA, USA, said the images have been "massively important" for his field, particularly in the Middle East, where they are "the starting point for all large-scale archaeology projects." But such research might just be the beginning. The availability of software for correcting distortions in the photos will permit more scientists to analyze them, Radeloff said. "In the next five to ten years, we will see a steep rise in the use of these images."

The Corona satellites required several technological leaps. In recognition of achieving those leaps, making it the first space-based Earth observation system, the US National Academy of Engineering awarded the Corona Project the Draper Prize in 2005. US President Dwight Eisenhower authorized the program in February of 1958 [7], just four months after the Soviet Union had launched Sputnik 1, the first artificial satellite to orbit Earth [8]. But Sputnik 1 was "a lump of metal," said Jesse Casana, a professor of anthropology at Dartmouth University in Hanover, NH, USA, who has been working with Corona images for more than 20 years. It carried no cameras or instruments, and it could not propel itself [9]. Although the Corona satellites, like Sputnik 1, were launched on rockets, they were expected to maneuver themselves into their final orbital path [10]. Once there, they had to maintain stability on all three of their axes—a feat no spacecraft had yet achieved [3]—so that on-board cameras could capture detailed photographs of Soviet missile sites and other militarily important locations. They then had to return those images to Earth for analysis. And to top it all off, the program's engineers had only two years to get the system working [10].

An indicator of the difficulty of these challenges is that the first 12 missions failed—well above the typical number for the time [10]. But the thirteenth mission flew successfully, and the fourteenth, launched in August of 1960, was the first to take photographs of the Soviet Union [10]. "It was an amazing engineering feat in the 1960s to be able to build an autonomously operating mapping system in orbit," said Jackson Cothren, a professor of geography at the University of Arkansas, Fayetteville, AR, USA.

Many of the innovations the Corona team devised became standard on later spacecraft. For instance, the satellites were the first to be equipped with gyroscopes that registered deviations on the three axes. The gyroscopes, along with a pair of infrared sensors that could recognize the horizon, kept the cameras aimed toward the ground and ensured stability during filming [11]. If one of the satellites detected it was tilting or rolling, it could correct its attitude by firing jets of nitrogen gas [11]. Today, a similar three-axis system keeps the Hubble Space Telescope trained on distant nebulae and other photographic subjects, and it remains one of the two major strategies for ensuring spacecraft stability [12,13].

The camera system that was essential for the Corona satellites dramatically improved over the course of the program. The cameras used custom-designed 70 mm film that combined broad ground coverage with high resolution [14]. Still, the earliest images were grainy (Fig. 1), with a resolution of typically 8–12 m [15,16]. As the Corona team refined the satellites' attitude control capabilities and their cameras with better lenses, later missions reached a resolution of less than 2 m [3,16,17].

Some satellites could shoot nearly 5 km of film [14], but no matter how much detail the photos revealed, they were useless unless intelligence analysts could examine them. At the time, however, "there was no mechanism to transmit a message of that resolution"

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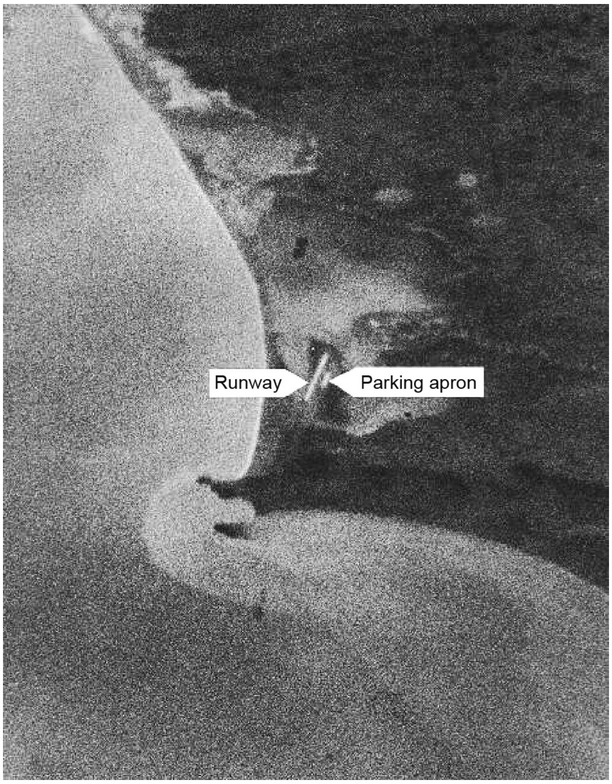

Fig. 1. An image from the first successful Corona mission in 1960 shows a Soviet landing strip in far northeastern Siberia. The resolution of the image is much lower than for photos taken by later missions that had superior lenses and better stability control. Credit: US National Reconnaissance Office (Wikimedia, public domain).

back to Earth, said Casana. The project's engineers came up with an audacious solution. Once a satellite had taken photographs, it pivoted, tilted earthward, and jettisoned a capsule containing the film [10]. Slowed by a retrorocket and by parachutes [18], the capsule drifted down over the Pacific Ocean until it reached about 4500 m. Then, a United States Air Force plane trailing a series of poles, lines, and hooks would maneuver until it was above the capsule and could snag the parachute (Fig. 2) [14]. Although this so-called bucket catch seems chancy, it worked most of the time and enabled the program to achieve several firsts. For example, the recovery capsule for the thirteenth Corona mission was the first human-made object to return from space [10].

By the early 1970s, the Corona program had outlived its intelligence-gathering role. But more than 20 years later, when researchers began getting their hands on the nearly 650 km of film the satellites shot, they quickly realized the images were a scientific gold mine because of "a unique combination" of qualities, said Cothren. In the Middle East, Ur noted, many archaeological sites have been swamped by reservoirs (Fig. 3), built over by enlarging cities, plowed under as mechanized agriculture expanded, or destroyed for other reasons. The Corona images allow researchers to resurrect those vanished sites. "They are like a time machine," said Ur.

The images have other virtues as well. Although today's satellites are capable of much higher resolution, the Corona film still offers greater detail than other widely used historical imagery, such as that from many of the Landsat satellites, the first of which launched in 1972 and had a resolution of 80 m [16,19]. The images are also easily accessible, Casana said. All of the original film still exists, and for only 30 USD researchers can obtain a high-resolution scan of a particular location from the US Geological Survey (USGS) [16]. In addition, Casana noted, "Corona provides continental-scale coverage. That makes it uniquely powerful."

Ur, who called the images "the foundation of my academic career," is one of the researchers who have exploited that large-scale coverage. He used the images to map more than 6000 km of pathways in Northern Syria and Northern Iraq, revealing an unexpected degree of interaction between communities in that area more than 4000 years ago [20]. The imagery has also been indispensable for Casana, who used it to census archaeological sites across the Middle East in 2014. At the time, researchers had pinpointed about 4500 such sites in the region, but by analyzing Corona photographs, Casana and colleagues identified another 10 000, including abandoned cities [4].

Despite such proven utility, the Corona images remain difficult to work with because they are so distorted [21]. The satellites shot long strips of film with a panoramic camera, and as a result the photos appear stretched, with resolution at the edges of an image lower than at the center [16]. Mountains and other topography, as well as the movement of the satellites, further warp the images. "To do any serious large-scale analysis, you need the image to be corrected," said Cothren. Recently developed software makes this task, known as orthorectification, easier. Radeloff and his team used a commercially available package to adjust the Corona images for their 2020 study. And Casana and Cothren co-direct the CORONA Atlas Project, which has orthorectified more than 2000 Corona images and now offers a free tool that lets researchers do

Fig. 2. In August 1960, a US Air Force plane attempts a bucket catch to retrieve the film capsule released by a Corona satellite. The capsule hangs just below the parachute the plane is about to capture. Credit: US Air Force (Wikimedia, public domain).

Fig. 3. On 1 August 1969, a Corona satellite shot this photograph of the ancient city of Samsat in southeastern Turkey. An important urban center for more than 3000 years, Samsat is now completely under water, flooded after the Ataturk Dam was completed in 1990. Credit: CORONA Atlas Project, US Geological Survey (public domain).

the job themselves [21]. Only about 5% of Corona images have been scanned, Radeloff said, and analyzing the remaining ones is important—it will allow researchers to "look into a different world."

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