Spy balloons: Modern technology has given these old-fashioned eyes in the sky a new lease of life

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The E-3 Sentry is an airborne warning and control system, or AWACS, aircraft. Planes like this form a vital component of US air defences. Credit: US Air Force, Author provided

The US military has now shot down four high-altitude objects that had entered American and Canadian airspace, raising questions about their purpose and origin.

The first of these objects, a Chinese balloon, was downed by a fighter jet on 4 February. While China says it was for weather monitoring, US officials say it was being used for surveillance. A knowledge of technology in this area throws up some clues about what may have been going on.

The balloon is believed to have supported a signals intelligence collection payload, although this has yet to be confirmed. Debris has now been retrieved from US territorial waters off the coast of South Carolina and will be transported ashore for analysis.

A further three objects were downed between February 10 and 12 over Deadhorse in Alaska, near Yukon in Canada and over Lake Huron close to the US-Canada border.

Signals intelligence, or "sigint", refers to electronic data, which could consist of conversations, written messages or data from weapons or radar systems. Sigint is normally collected by satellites, but can also be gathered from aircraft flying in international airspace.

Normally, satellites that collect sigint are positioned in low-Earth orbit (LEO)—say at 500 to 1,000km altitude—or at geostationary orbit, at the much higher altitude of 36,000km. Although the collection of this type of intelligence by satellites is efficient and reasonably effective, there are some limitations.

A satellite in LEO will complete an orbit around the Earth in 70 to 100 minutes but it will not pass the same point on the Earth again for 14 to 20 hours depending on its altitude. This is because our planet is also

moving. Even then, it will only be visible to a point on Earth for a maximum of 20 minutes; which is called its "dwell time". Increasing the number of satellites helps, but there will still be large time gaps in coverage.

In theory, a geostationary satellite could have a permanent dwell time. But, because it is positioned at around 36,000km from the Earth's surface, it could miss the collection of important but weak signals.

The US military has been developing signals—electronic data transmissions—with a low probability of intercept. This is making sigint collection by both Chinese and Russian spy satellites difficult. There will be large gaps in a 24-hour period when collection is not possible—a silent time.

China has attempted to close the gaps. In 2020, the country launched, to a 600km orbit, three new reconnaissance (spy) satellites from the Yaogan-30 series, as part of a wider network, or "constellation", called Chuangxin-5 (CX-5), bringing the number of satellites in the network to 21.

Steering ability

Enter the high-altitude "objects" that have been shot down over the US. Let's take the balloon that was shot down on February 4. By tracing this object's path over the US, it can be seen to have passed several highly sensitive defense installations, including silos for nuclear-capable intercontinental ballistic missiles (ICBMs) in Montana, US.

The balloon traveled across the US at an altitude of 20 to 30km and had the ability to steer in the upper atmosphere jet streams. Clearly, the advantage for sigint collection was that its dwell time was likely to be several hours, and its closeness to the surface of the Earth ensured that it

could, if it were spying, collect very weak signals.

Thus, a balloon that can remain undetected would be an ideal platform to augment the collection of sigint by both satellites and aircraft. Many countries have been employing balloons for intelligence gathering for at least 200 years, so the idea is not new and the advantages are well known.

Today's technologies have given this method of intelligence collection a new lease of life, as we've also seen from the use of small aerial vehicles—or "micro drones." Remaining undetected for a significant period is a key requirement to success. As to how this was possible in the US is an interesting question, given that the country has one of the best air defense systems anywhere.

One possible answer lies in the design of ground-based and airborne early warning system (AEW) radars. To reduce clutter on the radar, objects that are static such as mountains and towers are removed from the radar returns by making use of a natural effect known as "Doppler shift." When a train travels past you, the pitch of its whistle seems to change as it moves away from you. This is an everyday demonstration of the Doppler shift in sound waves.

The Doppler capability is common to all defense radars as they are focused on an aircraft and missile threat. A balloon or inflatable object, could be traveling at a velocity slower than the Doppler threshold and thus remain undetected.

Radar clutter

This shortfall in detection capability was recognized by NORAD (North American Air Defense Command) and radars have been reset to see very low velocity objects. However, the clutter will increase—perhaps

fulfilling one of China's aims to reduce the effectiveness of air defense radars.

A further difficulty with detection is the material used for balloons or objects. Plastics and synthetic inflation fabrics have no or very low radar reflectivity, thus adding another notch to their covert credentials. The balloon that started the current controversy in the US was first discovered visually and reported, rather than detected by air defense systems.

But the more recent discoveries over Canada and Alaska resulted from high-intensity surveillance. It has not yet been revealed what they are. Once that has been ascertained, the key question will be whether the objects were designed to penetrate the US defense system to gather better signals intelligence, or whether they were a test of US air defense systems.

It could, alternatively, be just a nuisance ploy. We shall know when the results of the balloon debris analysis are made known.

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