Balloon Shoot-Down Reveals New Insights On U.S., Chinese Capabilities

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A photo of the Chinese balloon over Modoc, Illinois, on Feb. 3 reveals potentially breakthrough design features for ultra-long-endurance, lighter-than-air systems.

Credit: Frank Melliere

More than two years before a U.S. Air Force F-22 shot down a Chinese spy balloon off the coast of South Carolina on Feb. 4, Zheng Zhenfeng, an employee for Taiwan's weather service, photographed a similar object floating high above Taipei, Taiwan, on Sept. 26, 2021.

Zheng's boss, Zheng Mingdian, is certain the two events are connected, revealing a perhaps yearslong, high-altitude spying campaign by the People's Liberation Army across the world using a new form of lighter-than-air technology.

- Japan, Taiwan and U.S. targeted by Chinese surveillance balloons
- Opaque fabric points to possible innovation

"The high-altitude spying balloons in the news have been around a long time, and [my] weather-agency colleagues took [pictures of] them two years ago," Zheng Mingdian, executive director of Taiwan's weather service, wrote on Facebook on Feb. 4. "Before that, there were photo records elsewhere, too, for many years."

The bizarre five-day, 2,000-mi. journey across the U.S. of China's apparent spy balloon revealed three important new insights: A Raytheon AIM-9X Sidewinder-armed F-22 can shoot down a floating object above 60,000 ft., U.S. officials believe Beijing has waged a yearslong aerial spying campaign with high-altitude balloons, and some experts think the Chinese vessel reveals a potential breakthrough of ultra-long-endurance, lighter-than-air technology.

The Lockheed Martin stealth fighter's capability to down a high-altitude balloon had never been tested or possibly even conceived, but the brazen violation of U.S. airspace prompted President Joe Biden on Feb. 1 to order a shoot-down attempt, White House officials say. Some criticized the decision to allow the balloon to cross the U.S. landmass, but military officials insisted the balloon's surveillance capabilities

posed no threat to national security. Military analysts also gained ample time to study the alleged spycraft's behavior and emissions, while the fighter-pilot community ran simulations to determine the best way to attack the unfamiliar target.

"I don't know that they've tested [the] AIM-9 at that altitude," says Gen. Glen VanHerck, the head of North American Aerospace Defense Command. "I'm not aware of any engagements against a high-altitude balloon such as this."

The F-22 from the 27th Fighter Sqdn. did not act alone on Feb. 4. Another F-22 flew armed and ready as backup in case the first shot missed. A high-altitude balloon—even a 200-ft.-tall balloon—presents a challenging target for a heat-seeking missile, with a dim thermal signature and a helium gas void within the envelope. The F-22 appeared to aim instead for a 70-100-ft.-long (20-30-m) horizontal truss dangling from a single line beneath the balloon—VanHerck compared its length to an Embraer ERJ 135 or ERJ 145. Ground-based civilian photography revealed that the structure carried 16 solar panel arrays and three inboard stations or pods.

The heat generated by the electronic systems appeared to be enough to provide a targeting lock for the imaging infrared seeker in the AIM-9X. The height of the target—60,000-65,000 ft.—still required the missile to ascend several thousand feet from a launch point at 58,000 ft., a senior defense official says. The result was a perhaps unlikely first air-to-air kill against a balloon by the U.S. Air Force's premier fighter.

"I'm really incredibly proud of everybody that took part in this, but the F-22 was remarkable," VanHerck says.

Two U.S. Navy ships—the amphibious landing ship USS Carter Hall and the survey ship USNS Pathfinder—are mapping and collecting pieces of the debris from the balloon that now lie scattered over an approximately 1 mi. X 1-mi. box about 50 ft. below the surface roughly 6 mi. off the South Carolina coast.

Sailors assigned to Explosive Ordnance Disposal Group 2 recovered the high-altitude surveillance balloon off the coast of Myrtle Beach, South Carolina, Feb. 5. Credit: Mass Communication Specialist 1st Class Tyler Thompson/U.S. Navy

In the age of hourly satellite overflights and relentless cyberattacks, an inflated surveillance system slowly drifting over Alaska, Canada and the continental U.S. appeared at first to stand as an unusual—inexplicable, even—one-off event. But the story quickly grew as reports emerged of similar balloon sightings around the world, including an ongoing balloon flight over South America, previous incidents in East Asia that had gone unexplained and a newly discovered trial of previous balloon flights over U.S. territory, including Guam, Hawaii, Texas and Florida. Instead of a singular provocation, a pattern has developed of Chinese spy flights by slow-moving high-altitude balloons, which had gone apparently undetected by U.S. surveillance systems.

"I will tell you that we did not detect those threats, and that's a domain awareness gap that we have to figure out," VanHerck says.

Although the previous overflights above U.S. soil had been missed, the intelligence community kept track of China's spying balloon campaign in other parts of the world. Congress was briefed about the program in August, White House spokeswoman Karine Jean-Pierre says.

"There has been a program that has been in effect," Jean-Pierre adds. "We have kept Congress abreast on that. But I don't have anything more to say or to share."

In fact, the evidence for such a spy effort has been available in the public domain for several years, but the shock of the U.S. overflight helped bring it back into focus. In addition to high-altitude balloon sightings over Taiwan in September 2021 and March 2022, Japanese government officials reopened reviews of similar publicly reported overflights of Japan in June 2020 and 2021.

When a similarly spherical white balloon flew near Miyagi prefecture in northeast Japan in 2020, photos of the object showed a perhaps earlier version of the technology that entered the U.S. on Jan. 31. In that case, the dangling support truss supported 24 solar panel arrays, payloads and a crosswise boom. The latter appeared to include a set of outboard-mounted propellers. It was not clear if the propulsive devices were being used to steer the balloon or the structure housing the payload.

By contrast, images of the latest balloon captured by photographers on the ground with telephoto zoom lenses appear to show a major evolution in the design of the payload module, including one-third fewer solar panels, three inboard payload modules and no clear evidence of any propellers.

Such long-distance visual evidence contrasted with remarks by John Kirby, the National Security Council spokesman. "It had propellers," Kirby says. "It had a rudder, if you will, to allow it to change direction." Civilian photos provided no signs of a rudder aboard the balloon, and it is not clear how such a control surface would help steer a spherical, slow-speed object. Kirby also may have been speaking metaphorically about a rudder.

In any case, members in the high-altitude balloon community have identified potentially significant technology advances exhibited by the Chinese vessel.

The few examples of ultra-long-distance, high-altitude balloons, such as Google's canceled Loon project, share a few common traits: a pumpkin-shaped, superpressure envelope, internal ballonet and translucent fabric.

The final item in that list is essential for regulating the temperature—and therefore pressure—inside the helium envelope. A translucent fabric allows most light to pass through the balloon without heating the helium gas inside.

But the Chinese balloon appeared to use an opaque fabric over a pumpkin-shaped helium envelope. If confirmed, China's program may have been the first successful design to use a helium envelope covered by a fabric that reflects the Sun's energy rather than letting it pass through, says Dan Bowen, a former balloon systems engineer at Project Loon. The result suggests a breakthrough by creating a more efficient system to regulate temperature without adding too much structural weight.

"I'm sure the rest of the world will quickly investigate this," Bowen says in an analysis released on Stratospheric Balloon Science, his YouTube channel.

The most advanced ultra-long-endurance, high-altitude balloons seldom use propellers for directional control. Instead, such aircraft pump regular air into an internal ballonet envelope to descend or release the air to climb, Bowen says. Altitude adjustments are made to find wind currents moving in other directions. The system provides a limited capability for directional control.

U.S. researchers have worked on similar technology with the Strat-OAWL (stratospheric optical autocovariance wind lidar) device, which Ball Aerospace flew on DARPA's Adaptable Lighter-Than-Air (ALTA) balloon in 2019. ALTA was aimed at demonstrating a high-altitude, lighter-than-air vehicle capable of windborne navigation over extended ranges and, according to DARPA, could navigate without independent propulsion by changing altitudes in excess of 75,000 ft.

A key element of ALTA was development of a Winds Aloft Sensor, which in the case of the DARPA project could send real-time stratospheric wind measurements back to the ground. The Ball Strat-OAWL system, which dates back as far as 2004 to proof-of-concept hardware efforts, is designed to measure winds from aerosol backscatter at the 355-nanometer or 532-nanometer wavelengths.

Meanwhile, the debris recovery effort also may help answer questions about the capabilities of the Chinese balloon's alleged surveillance payload. The decision to allow the balloon to cross the U.S. before shooting it down was based on a military assessment that the onboard sensors provided no threat, Kirby says.

"The time that we had to study this balloon over the course of a few days last week we believe was important and will give us a lot more clarity not only on the capabilities that these balloons have, but what China's trying to do with them," he says.

U.S. AIR FORCE (USAF) LOCKHEED MARTIN LOCKHEED MARTIN F-22