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CHINESE BALLOONS OVER NORTH AMERICA

ELECTROMAGNETIC RADIATION MODULE ACDB5009

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Background

A high-altitude balloon, released from China, was spotted entering American and Canadian airspace. [1]

Due to its flight path over United States' (US) military bases containing Inter-Continental Ballistic Missiles (ICBMs), America believed the device to be a surveillance balloon. [2] (Figure No.1)



Figure 1 – Flight path of high-altitude balloons released from China. [3]

China claims the balloon is for meteorological purposes. Stating the device is a civilian airship, which had deviated from its planned route because of poor weather and steering capabilities. [4]

Overall, a high-altitude balloon flew over America which originated from China. Due to its flight path and advanced technologies for a weather balloon, America shot it down.

Issues

1. It is unknown if the UK, or its allies, can detect and track weather balloons flying within their airspace.
2. Synthetic-Aperture Radar, and multispectral imaging are the biggest risks to security due to the information that could be collected.

Recommendations

1. Assess current radar abilities to detect and track high-altitude balloons.
2. Determine accuracy and fidelity of utilising SAR technologies to develop 3D models of assets.

Timing

1. Recommendation No.1 must be completed ASAP to determine security gaps.
2. Funding must be made available within 1 year to develop understanding of SAR technologies.

Discussion

Device Possibilities

There are four different possibilities which the device could be. These are:

1. A weather balloon. The Chinese claim that the device is a civilian airship used to capture meteorological data and has deviated off course is true. [4]
2. A probing device. The Chinese, under the guise of a weather balloon, have developed the device to probe America's defences; being used to test America's radar capabilities, and to identify gaps.
3. A spy-balloon. America's accusation is correct in which the "weather" balloon cover is fictitious. The device is used to capture various sources of data and communicates it back to Chinese intelligence. [5]
4. A weapon. This has been omitted from the report due to the Chinese claiming ownership. Additionally, there are more sophisticated methods of delivery.

Weather Balloons

Traditional weather balloons are high-altitude floating devices (<1500 m) which use helium or hydrogen in a balloon. They carry instruments which measure the atmospheric pressure, temperature, humidity, and wind speed by using a radiosonde. [6] The weight of a radiosonde is 250g – 500g and can be lifted 100,000 ft into the air. [7] The balloons usually last 2 hours and can drift 125 miles. Usually, the equipment is lost during travel.

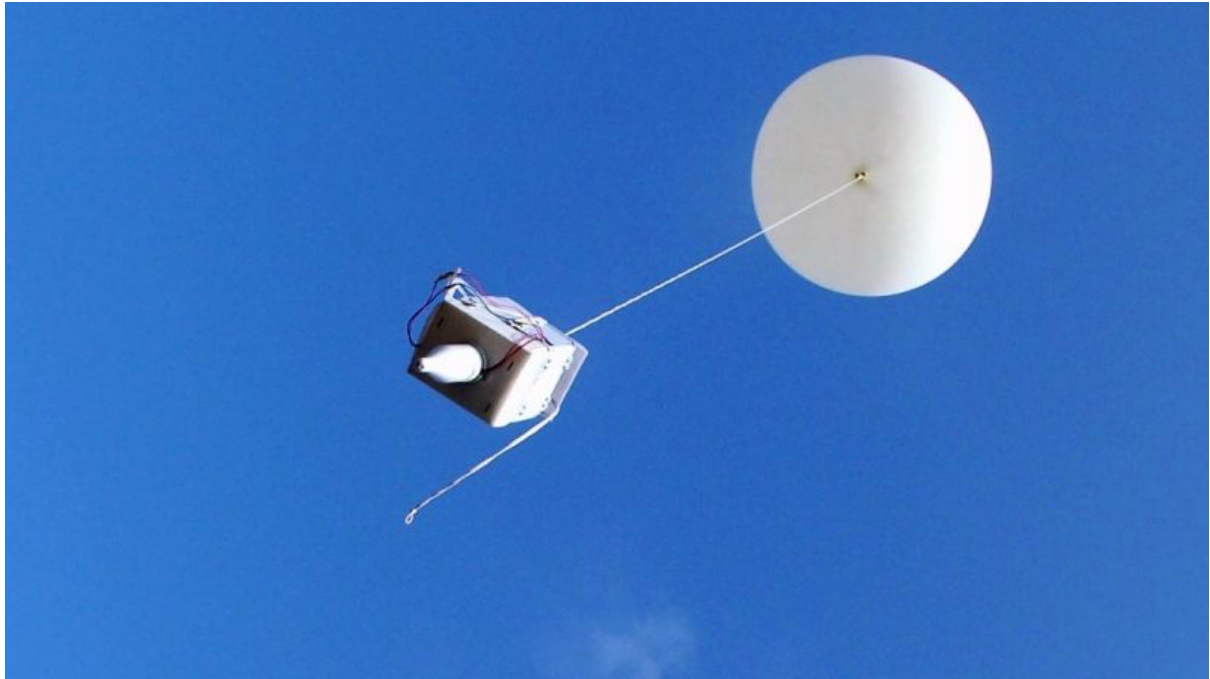


Figure 2 - Example weather balloon and radiosonde.

It is highly unlikely the device is a weather balloon due to:

- **Distance Travelled.** It is unlikely the Chinese needs weather data from America. If this data was required, China could have directly asked. Additionally, the device has been designed to travel further than conventional weather balloons.
- **Recovery of equipment.** The suspected device contains solar panels and carries a larger payload than a traditional weather balloon. The size, and investment in equipment hints there are other purposes for the on-board equipment. Especially since for traditional weather balloons the equipment is not recoverable. There are alternative, cheaper methods to collect weather data.

Device Characteristics

Sources have indicated the device can produced 10 kW of energy from its solar panels; float 18 Km above sea level; carry a payload above 900 Kilograms; and uses a 45 m diameter balloon filled with helium. The payload volume has been assessed as three buses ($\sim 260 \text{ m}^3$) and contain various sensors. [8]

Assuming the solar panels are 4m^2 per cell, and are 20% effective, and have 10 hours of sunlight, they will be able to produce 5.3 kW of energy. This is half the calculated amount. However, this could be a result of more detailed knowledge of the efficiency of the system, and a conservative estimate of sunlight hours. [9]

Device Signature

America claimed it detected the weather balloon entering its air space and monitored the device along its journey. [4]

Based on a commercial air traffic control radar (ASR 8), which can be used to detect aircraft up to 111 Km, this claim is feasible. [10] Taking into account the radar equation (Equation No.1), and inverse square law (Equation No.2), it can be argued as the device is closer and has a larger cross section, the ASR 8 will be able to detect the balloon.

$$P_r = \frac{P_t}{4\pi r^2} \sigma \frac{1}{4\pi r^2} A_{eff}$$

Equation 1 - Radar Equation. [11]

$$intensity \propto \frac{1}{distance^2}$$

Equation 2 - Inverse Square Law [11]

The weather balloon reported to have little to no thermal signature due to acclimatising to the local environment. [12] It was visible to people on the ground using cameras. Appearing as a white orb on a blue background. Additionally, it has been reported the device could upload and download data. [13] Therefore, indicating it has an electromagnetic signature.

Overall, it is possible the device could have been used to probe the United States defences, to determine if their radar could detect a mass, moving in a direction at a set velocity and height. There has been reports of multiple balloons flying over the states. This could be a strategy to probe for weaknesses to determine radar blind spots. [14]

Surveillance and Communication Methods

Radio-waves and Micro-waves

Antennas can be utilised to conduct traffic analysis, and to identify channel signatures. Using a combination of ultra-wide (UW) omni-directional antennas, and UW directional antennas, a range of frequencies can be detected.

The omni-directional antennas are used to detect radio waves from any angle. However, as waves collide into other radio waves, they will interfere with each other causing constructive or destructive interference. Therefore, the data will need to be separated using frequency-division multiplexing. This will separate the wave received into the separate frequencies. Once a frequency of interest has been identified the UW directional antenna can be used to locate the source.

During the balloons flight over military bases, traffic analysis could be conducted to determine patterns in activities, frequencies used, and radio waves emitted. [15] This data is important because if an adversary know a response to a certain frequency, they can predict responses upon the frequency being detected. A historic example is the British using fake military bases but

still sending commands via RF. When the Germans conducted traffic analysis, they received messages giving them the illusion of functional military bases. [15]

Defence mechanism from traffic analysis are:

- Changing polarisation
- Coding time of arrival
- Multiple Transmitters
- Changing Frequency

The final defence is encrypting data. Therefore, if data is captured from man in the middle attacks the data will be protected against interrogation.

Synthetic-Aperture Radar

Synthetic-Aperture Radar is the use of reflected microwaves to create a 2D or 3D model of a landscape and/or object. A range of frequencies are emitted from the antenna towards the ground. As the waves reflect from the ground the change in polarisation is processed producing a 3D model. [16] Advantages of utilising SAR is greater spatial resolutions than conventional radar. Additionally, SAR can penetrate clouds and aerodrome canopies. However, the disadvantages of SAR is slow data acquisition, power requirements and require a stationary or slow moving target. The threat of SAR to security is the capability to create 3D models of sensitive assets, even when covered by light materials. Therefore, providing data to defeat platforms via reverse engineering.

Data Transmission

Reports stated the device can upload and download data. [13]

This is most likely via satellite through line-of-sight propagation using microwaves due to the operating frequency range of 300 MHz – 300 GHz. Assuming 1 bit of data is equal to one hertz, this results in 35.76 MB/s – 34.92 GB/s upload/download speed. Therefore, the device has the capability of

sending videos, images, and other information deemed valuable by the Chinese.

Additionally, by using directional microwave transmitters, this reduces the power required to transmit data. An omni-directional transmitter would increase the device's radio-signature, while also increasing the power requirement to transmit data.

It is unlikely the device receives information from the ground. Due to the height, and distance from the mainland. The signal would be weakened due to the inverse square law. Additionally, attempting to send a signal by reflecting a radio wave off the ionosphere could be intercepted and would raise suspicion.

Global Navigation Satellite System and Weather

China has its own global Navigation Satellite System (GNSS) called BeiDou. It has both civilian and military channels and has the ability to encrypt data. The frequency it operates is 1207MHz (Microwave) and used binary phase shift keying to transmit data. [18]

The device would have the ability to upload its position to the network, informing users of its location. Therefore, data collected would have a location at which it was collected. Useful for taking weather samples or knowing the locations of sensitive data captured.

Microwave can also be used to penetrate clouds to measure wind directions and patterns near ocean surfaces. [19] Therefore, as the device approached US airspace, using weather patterns and GNSS a path could have been determined using natural forces. As a result, having an excuse or reason why the device is flying over military air bases.

Further research should be to determine if multiple wind currents were used or a singular current which crossed America. This would indicate if steering capabilities were used to jump wind currents to continue its journey.

Infra-red Radiation

Signature Detection

The balloon may have infrared sensors which can measure thermal radiation. This could be used to measure the heat signature produced by military platforms being used in military bases. This data can then be used to assist the research and development of systems which seek the recorded heat signature. Thermal cameras on satellites do exist. However, if the same thermal camera was brought closer to the surface for a longer period of time, better images could be captured.

Missile Tracking

Satellites have been used as early warning systems for ICBMs as they measure the increase of infrared-radiation produced by the plume of the propelling rocket. [20]

Therefore, it is possible the device was sacrificial to record and identify the incoming missile plume used to deactivate it. Thereby allowing an early warning system against future threats by detecting the infrared radiation produced by future systems. Additional advantages of using a sacrificial system is distance would be negated. However, the American deployed jamming techniques to prevent data being transmitted by using jets. Therefore, this scenario, while likely, is unlikely to be effective methods of capturing data.

Multispectral Imaging

Hyperspectral imaging is the identification of all spectrums per each pixel of the image. This creates hyperspectral cubes in which each layer reveals the next

slice of the electromagnetic spectrum. Resulting in large files and identifying parts of the spectrum not desired. [21]

Multispectral imaging achieves the same function, although is programmed to detect 3 – 10 wavelengths instead of the entire wavelength. Reducing the file size and identifying wavelengths important to the user. The benefit of multispectral is the quick comparison of wavelengths allowing easier identification of objects. Military applications have been used to detect landmines and ballistic missiles. [22]

The device should use multispectral imager instead of a camera in the visible, thermal or ultra-violet domain. This is because the multispectral imager can achieve all the functions from each domain while combining all the information. Therefore, giving a better understanding for object identification and providing the EM profile of the assets. However, it is unlikely the device will have a multispectral imager as this would remove the disguise of a weather balloon.

Visible Light

Aerial images could have been captured from the device, revealing information about facilities, equipment, or experiments being conducted outside. The benefits of using a weather balloon compared to satellite imagery is a weather balloon is closer to the subject and can spend more time over an area. This allows greater data capture, while also improving the sensors' ability to "see" an object. Unfortunately, clouds can form at 6 Km. Therefore, the weather balloon, like satellites, will not be able to penetrate clouds.

Ultra-Violet

Detection of Camouflage

Ultra-violet (UV) can be used to identify vehicles and other materials which may be hidden in the visible domain using camouflage. This could identify assets which are trying to be hidden from satellite imagery. However, this can easily be defeated by keeping assets indoors as UV has poor penetrating power.

Secret messages could also be written and revealed in the UV domain. While a detailed message is unlikely to be sent due to the resolution, a mark or signal could have been conveyed. However, this is unlikely as a satellite could be used to capture a tell that has limited information.

Chemical Processing

All chemicals emit ultraviolet radiation at different frequencies. One report has mentioned the use of UV to identify chemical agents. Therefore, it is possible an UV sensor was used to detect chemical processing and manufacturing plants. This could be used to identify waste materials from manufacturing plants in order to determine chemical components of weapon fills. [23]

Additionally, it could be used to determine if the agreement of the Organisation and Prevention of Chemical Weapons agreement was broken with unregulated testing. However, very unlikely due to the political consequences if it were so.

X-Rays and Gamma Rays

X-rays have been used on satellites to detect nuclear testing and uses. During the nuclear reaction there is a release of x-ray particles and gamma particles. If multiple sensors were utilised, the release of EM waves could be detected and triangulated. Thereby being able to locate and monitor future testing and uses. However, due to America's current agreements this is very unlikely. Therefore, there are unlikely to be sensors which can detect gamma and x-ray particles on the device. [24]

Additionally, it is very unlikely the device has the power to produce X-rays at 18 Km. Due to the distance the x-ray particles would be absorbed and lose power due to the square inverse law. Additionally, the onboard power supply is not sufficient to produce a strong emission. Therefore, no meaningful information can be gained from X-rays at 18 Km.

Summarising Points

- It is unlikely the device is a weather balloon, due to the technologies implemented, and reports that were leaked / released from the United States. [8] [23] Additionally, it is very unlikely to be a weapon due to the Chinese claiming the device, and the political affect it would have if it were to be a weapon.
- The device is likely to be a surveillance balloon used to probe America's defences for weaknesses. Reports have confirmed it has the potential to be using radio-waves, SAR, and other undefined sensors to collect information.

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