**All-domain Anomaly Resolution Office**

*U.S. Department of Defense*

**Case: "Mt. Etna Object"**

Case Resolution | 28 April 2025

## AARO Assessment and Case Status

AARO assesses with moderate confidence that the object was a balloon. AARO assesses with high confidence that the object did not exhibit anomalous behavior.

## Case Overview

In December 2018, a shortwave infrared (SWIR) camera onboard a U.S. military uncrewed aerial system (UAS) operating near U.S. Naval Air Station Sigonella over the Mediterranean Sea south of Sicily, Italy, captured 12 minutes of infrared video of an eruption of Mt. Etna. For approximately four and a half minutes, a round object appears on the video and seems to exhibit anomalous performance characteristics by moving at high speeds and transiting a superheated gas and ash plume produced by the eruption.

The UAS operator reported that the object's flight behavior was seemingly unaffected by transiting the plume, with no discernable impact on its performance, altitude, or bearing. The operator reported the object's speed as approximately 555 kph (345 mph).

### Case Synopsis

**Location:** Mt. Etna, Italy

**Date:** December 2018

**Object Altitude (reported):** 500 feet
**Object Altitude (assessed):** 15,000 feet

**Object Speed (reported):** 345 mph
**Object Speed (assessed):** 24 mph

**Object Shape (reported):** Round
**Object Shape (assessed):** Spherical

**Reporter:** U.S. Military UAS operators

**Data Type:** Infrared

**Reported Behavior:** An object moving at high speeds through Mt. Etna's ash plume.

**Assessed Behavior**: The object did not demonstrate anomalous performance characteristics.

**Confidence:** Moderate confidence the object was a balloon. High confidence the object did not demonstrate anomalous performance characteristics.

## Key Findings

AARO assesses with high confidence that:

- Optical effects, turbulent atmospheric conditions, and limitations in sensor capability distorted the object's apparent behavior, leading to an inaccurate initial assessment of its performance characteristics.

- The object did not exhibit anomalous speeds or other behavior exceeding known state-of-the-art performance characteristics. It did not pass through the volcano's ash plume.

**Performance Characteristics**

**Object Speed:** AARO assessed that the object's speed was approximately 39 kph (24 mph), moving generally west-to-east, consistent with wind speed and direction. The object's apparent high speed is attributable to motion parallax. Motion parallax is an optical effect that induces an observer to perceive that a stationary or slow-moving object is moving much faster than its actual speed when viewed from a moving frame of reference. The more quickly an observer moves relative to an observed object, the more pronounced this effect is. The UAS platform's relative motion made the object appear to move at high speeds.

**Object Flight Path:** AARO estimated the object's distance from the UAS platform by comparing its speed, the cloud deck's apparent motion, and the wind speed to plot its trajectory. Applying this methodology, AARO created a model that accurately predicted the object's location later in the video, validating the conclusion that the object moved at wind speed and heading. (Figure 1) This predictive model aligned with the findings of an independent 3-D model produced by an AARO partner, further validating the methodology.

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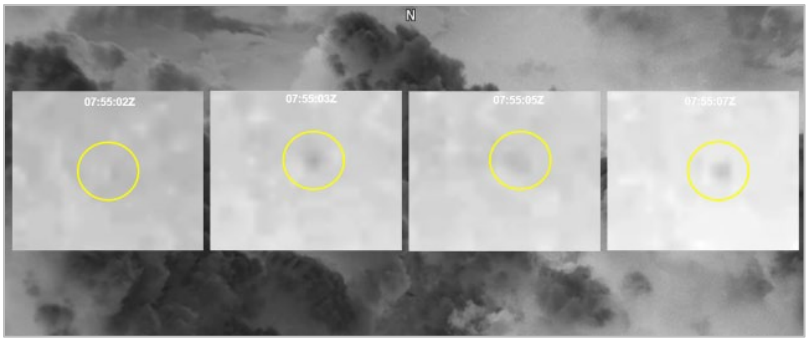


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*Figure 1: Predictive trajectory analysis revealed the object's position when it was visually undetectable. Pixel examination using post-processing filters rendered the object visible, validating this approach.*

**Apparent Anomalous Material Properties:** AARO applied comprehensive full-motion video (FMV) analysis, 3-D modeling, pixel examination, and wind speed calculations to assess that the object was much closer to the SWIR sensor than initially reported. The object did not pass through the volcano's ash plume. The object was approximately 170 kilometers (106 miles) away from the plume during the recording. AARO conducted a comprehensive FMV analysis to conclude that the object was approximately 30 km (19 miles) from the SWIR sensor. (Figure 2) AARO also applied kinematics and photogrammetry techniques to develop a 3-D model of the event.

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Figure *2*: *AARO's top-down reconstruction of the event depicting the object's distance from the UAS platform. (not to scale)*

**Observable Characteristics and Attribution**

**Size and Shape:** AARO employed pixel examination to conclude with moderate confidence that the object was spherical. Its approximate diameter was 0.3 meters (1 foot). (Figure 3)

**Attribution:** Due to the object's size and performance characteristics, AARO assesses with moderate confidence that the object is a balloon.

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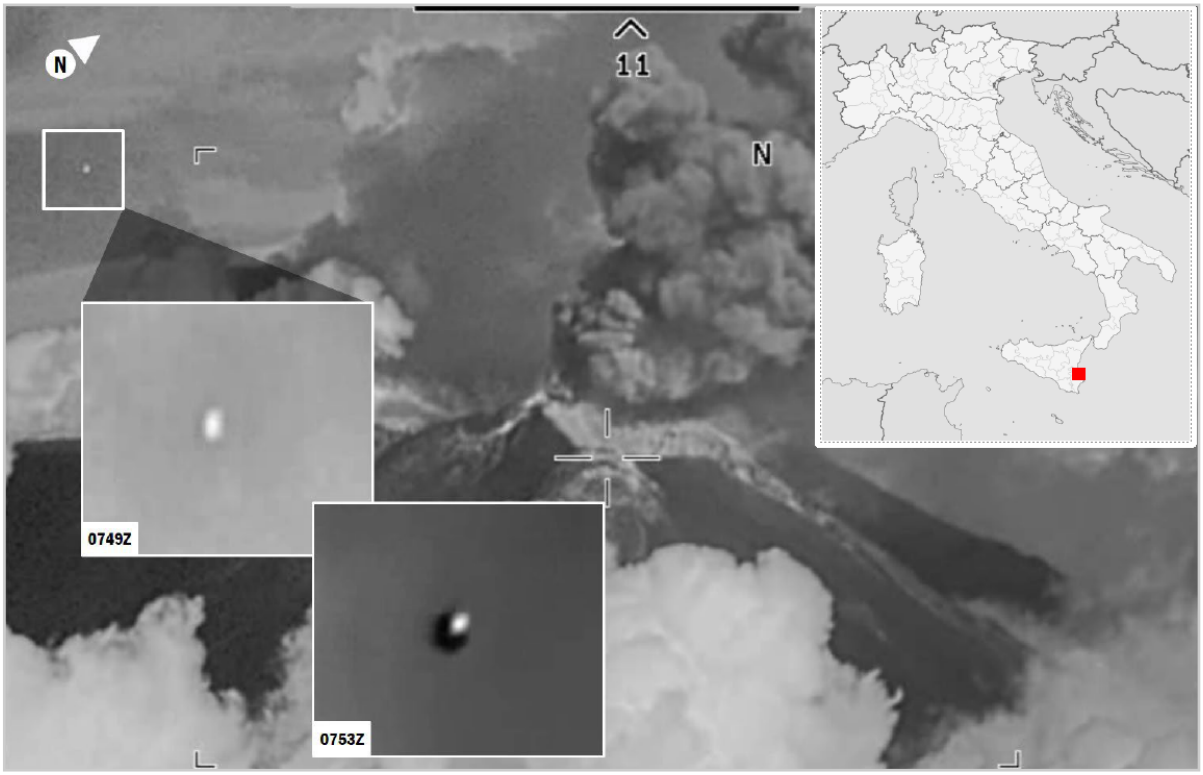


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*Figure 3: The object at a higher magnification (0749Z) and enhanced using post-processing tools (0753Z). The object is spherical with an approximate diameter of one foot.*

**Data Quality and Methodology:** AARO assesses that the sensor data associated with the event provides sufficiently detailed information to resolve this case with moderate confidence. However, sensor limitations and atmospheric turbulence constrain the modes of rigorous analysis that can be applied to identify the object conclusively.

**Sensor Effects and Limitations:** SWIR sensors identify targets by detecting differences in infrared energy relative to the surrounding environment. Cool objects predominantly reflect shortwave infrared energy, while hot targets predominantly emit shortwave infrared energy. These sensors do not employ active range finding, and obtaining the accurate range to a target is highly dependent on environmental factors. The thermally turbulent atmospheric conditions near an actively erupting volcano likely disrupted the sensor's ability to capture accurate data. Volcanic ash, composed of fine particulates, scatters and absorbs infrared radiation in unpredictable ways, creating a “noisy” thermal environment. These conditions further reduce the sensor’s accuracy by distorting the object’s signature.

The UAS platform’s SWIR camera was optimized for air-to-ground observation rather than air-to-air detection during the encounter. In this configuration, SWIR sensors cannot detect and track airborne objects reliably and cannot provide an accurate range to the object. Airborne objects recorded by sensors configured in this way often appear indistinct, blurry, or featureless, even if they would have visually observable surface features under different collection conditions.

These factors likely influenced the reporter's perceptions of the event, leading to unreliable initial conclusions about the object's speed and performance characteristics. AARO cautions that the SWIR sensor's image data should not inform any conclusion of the object's performance characteristics because of the significant limitations imposed by atmospheric turbulence, post-processing effects, and contrast stretching. These effects produce visual artifacts such as flickering, pulsating, and luminosity differences, significantly reducing the reliability of traditional FMV analysis and pixel analysis techniques.

**Alternative Hypotheses**

**Anomalous Performance Characteristics:** An AARO partner's initial assessment suggested the object may have moved up to 5,470 kph (3,400 mph) and that it transited the volcano's ash plume. AARO and its other partners do not concur with these findings. AARO's pixel examination analysis determined that the object was much nearer to the sensor than initial estimates, exacerbating the effects of motion parallax and leading to an incorrect assessment of the object's speed.

An AARO partner compared the luminosity of the object's pixels to those around it and assessed that the object's gradient luminosity remained constant before, during, and after it appeared to transit the plume. This conclusion would place the object within the volcano's ash plume. AARO and its other partners do not concur with these findings because the UAS platform's SWIR sensor cannot provide accurate range-finding data given the atmospheric turbulence. AARO produced a validated 3-D model demonstrating that the partner's assessment depends on unreliable and inaccurate input data.

**Bird:** Initial assessments from AARO's partners found that the object appears to flicker in the sensor display at a steady frequency, which is highly suggestive of a bird flapping its wings to maintain steady flight. On further analysis, AARO's partners found that thermal turbulence, post-processing effects, and contrast stretching produced visual artifacts such as flickering, pulsating, and luminosity differences in the video footage. Therefore, AARO and its partners discarded this initial assessment, concurring that the object was unlikely to have been a bird and was likely a balloon.

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