**An Investigation of New Philadelphia**
**Using Thermal Infrared Remote Sensing**

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A thermal infrared survey of the New Philadelphia site was conducted by Bryan Haley of the University of Mississippi and Tommy Hailey of Northwest State University in conjunction with Chris Fennell of the University of Illinois at Urbana-Champaign. A Destiny 2000 Powered Parachute (PPC), piloted by Hailey, was used as a platform for an Agema 570 thermal infrared camera for the survey. The goal was to identify anomalies that might be related to the historic occupation of the town.

## Thermal Infrared Methodology

A target is discernible in thermal infrared data only if the physical properties of the materials differ enough to produce a contrast. These properties include conductivity (k) and volumetric specific heat (Cv), which is the amount of heat stored per volume over a given period of time (Perisset and Tabbagh 1981:170). Using k and Cv, a single property called thermal inertia (*P*) can be expressed as *P* = the square root of (k Cv) (Perisset and Tabbagh 1981:170). The higher the thermal inertia, the more resistant the material is to changing temperature. For soils, thermal inertia increases with the amount of moisture because the conductivity increases.

The real utility of an archaeological prospection technique is in delineating buried targets. For thermal infrared, the properties of a superficial layer covering a feature and the surrounding matrix are critical. A thermal anomaly is attenuated as either the conductivity or the depth increases. Therefore, wet soils and deep features are not ideal. The maximum target depth that can be detected diurnally is probably around 40 centimeters (Ben-Dor et al 1999:124). Long term studies may be able to reveal targets as deep as 2 meters in some cases (Nash 1985:77), but the data is very difficult to collect.

The thermal behavior of a material over time is dynamic. For short term studies, the diurnal heating cycle creates the most important temperature changes. The best time for maximum anomaly contrast is just after sunrise or just after sunset (Figure 1), although the exact time is difficult to predict. The anomaly amplitude will also be inverted between these times (Ben-Dor et al. 1999:118).

One other important consideration is the ground cover on the survey area when the data is acquired. Bare earth is desirable and it has yielded relatively subtle, prehistoric Native American features (Haley 2004). Thermal infrared has been used infrequently on vegetation-covered sites, although recent research (Kiesow 2005) suggests that it may be used to enhance crop marks on Roman villa sites.

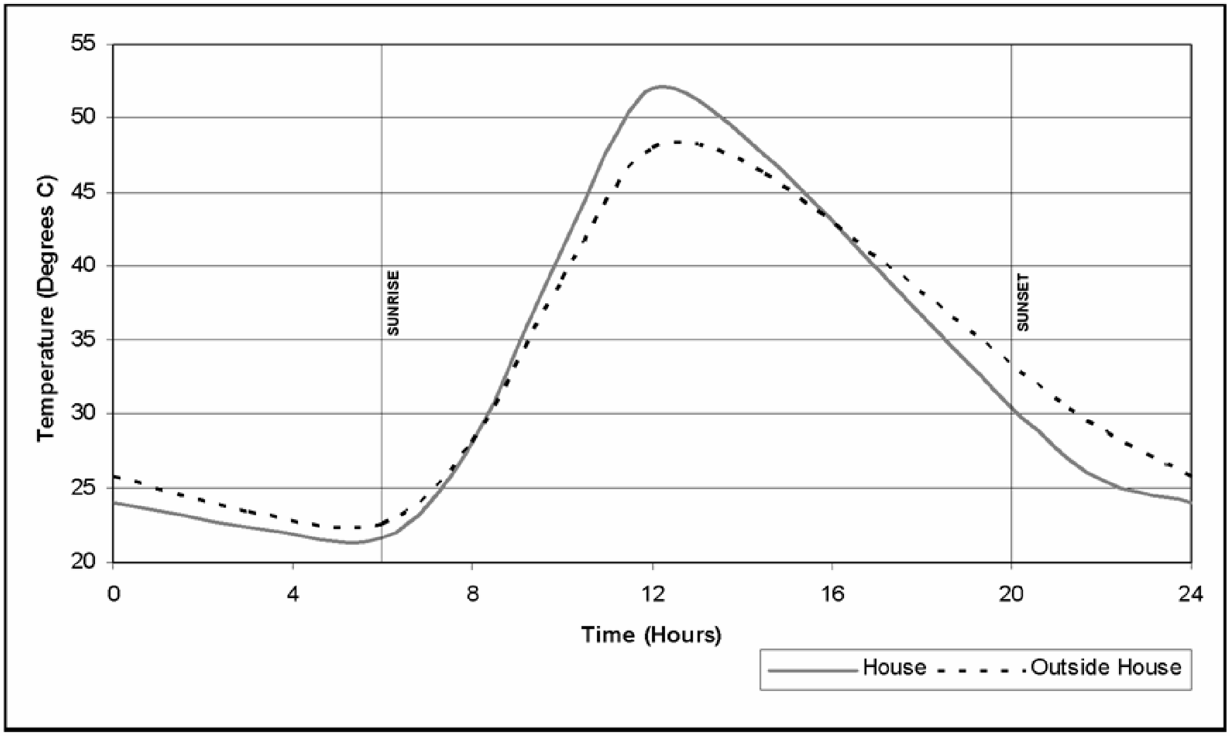


*Figure 1. The thermal variation of a hypothetical buried Mississippian house versus the surrounding soil matrix for a 24 hour period.*

## Survey Area Description

The ground cover varied considerably at the New Philadelphia site during the time of the flyovers. A small area, just to the east of the turnoff to the road into the site, was mowed to a height of a two inches or less. The ground in this area also appeared to be affected by cars repeatedly parking there. To the west of the road into the site, the grass was mowed recently, but it had grown up taller than the first area. Tracks caused by mowers were also visible there. The rest of area was in tall grass, mostly between one and three feet in height. To the east of the main site core, town blocks were staked out and they were highlighted with types of grass. In other areas, mostly to the northwest and southeast of the site core, shrubs and trees were present. To the west, terraces were visible and it was apparent a considerable amount of soil modification had taken place. There was water pooling around some of these features. In short, the ground cover conditions were not optimal for thermal infrared survey.

## Research Design

The Destiny 2000 Powered Parachute (PPC) is a two-seat experimental aircraft that is ideal for archaeological reconnaissance (Hailey 2004). The PPC is a low speed, minimal vibration, and flexible altitude aircraft – all essentials for the acquisition of high quality images (Hailey 2005:74). Also, the two seat configuration allows for passenger in the front seat to focus on flying the passenger in the back seat to acquire images (Hailey 2005:74). One limitation of the aircraft is the need for surface winds of less than approximately 12 miles per hour (Hailey 2005:76).

An Agema Thermovision 570, a broadband thermal infrared camera manufactured by Flir Systems Incorporated, was used for data acquisition. The Thermovision 570 is capable of measuring differences of temperature to .2 degrees Celsius and at wavelengths of 7.5 mm to 13 μm (FLIR Systems 1996:8-1). The camera has a 24 by 18 degree lens and produces a digital image composed of 320 by 240 pixels with a Focal Plane Array detector (FLIR Systems 1996:8-1). When used at an altitude of 100 meters, the camera and lens combination produces a field of view of 42 by 32 meters and a spatial resolution of about 13 centimeters at (FLIR Systems 1996:8-3).

To allow the images to be georeferenced to a standard coordinate system, targets constructed of aluminum flashing were placed around the survey area. The positions of these targets were determined using a Trimble ProXRS deferential Global Positioning System (GPS). The images were georeferenced using a combination of ArcGIS 9.2 and Erdas Imagine 8.7 software, generally using a first order or second order polynomial transformation. In these cases the images were near vertical, allowing the simply transformation method. In some cases however, flight lines forced images to be taken from an oblique angle, requiring a rubber sheeting method to be used.

*Figure 2. Agema 570 thermal infrared camera.*

Since it is difficult to predict the best time to acquire thermal images to reveal targets of a certain depth, images were taken during both morning and evening flyovers. The best two sets were taken on the morning of May 16, 2008 and the evening of May 17, 2008.

**Results**

Image composites for morning and evening data are shown Figure 3. There is a considerable amount of variation between the two data sets. The morning image is dominated by surface features and, as a result, it is difficult to identify anomalies that might be archaeologically significant. There is extensive shadowing visible to the west of the trees and this is probably highlighting the surface features.

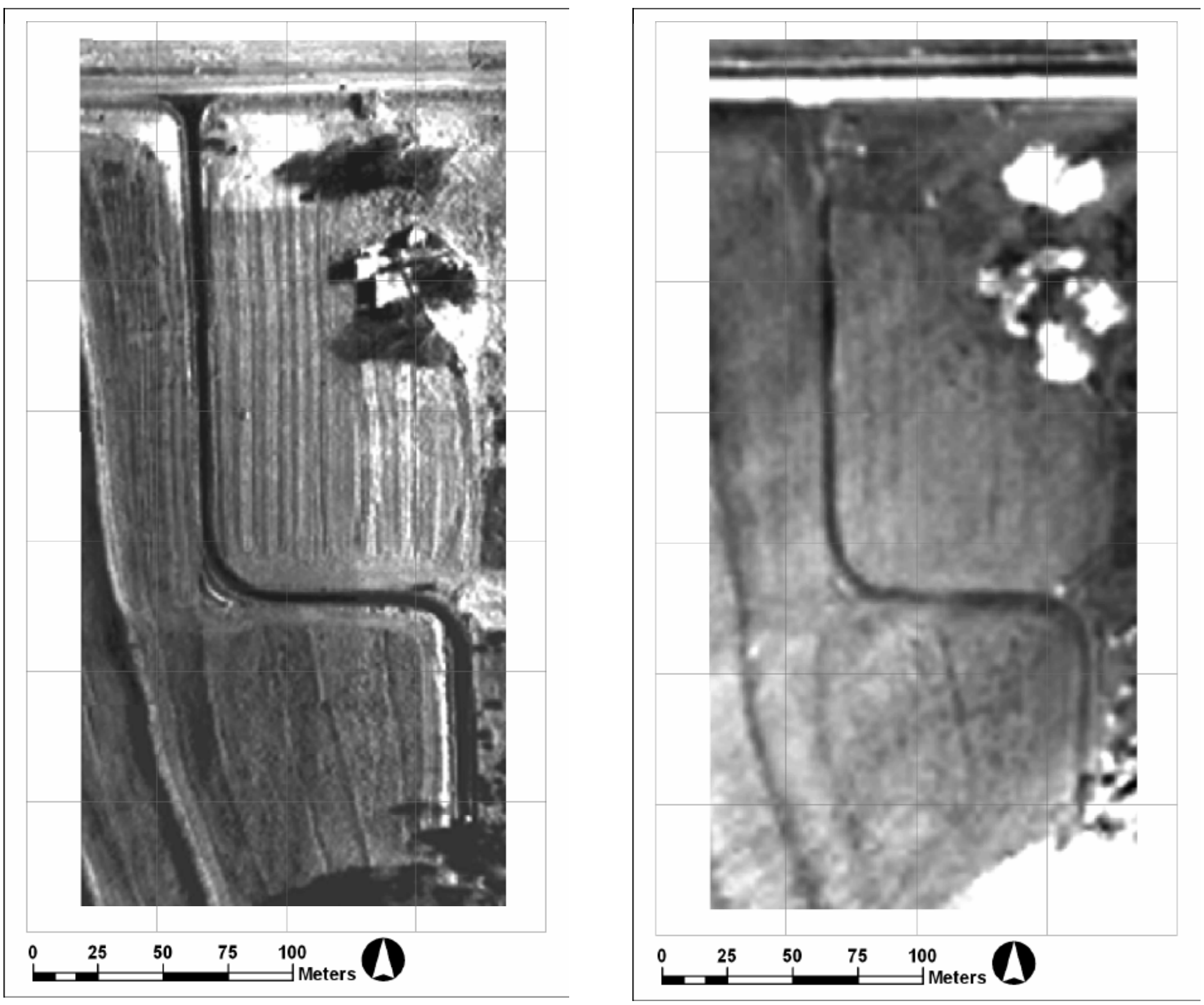


*Figure 3. Morning (left) and evening (right) thermal infrared composite images.*

Unfortunately, it was not possible to avoid shadowing in the morning data. Flying earlier, before the sun is high enough to cause shadowing, would decrease the amount of heat that penetrates into the ground. The chances that buried archaeology would visible are very small. Flying late enough in the day to eliminate shadowing would not be safe.

The surface features were deemphasized in the evening data since flights were just before or just after sunset. There are more features of potential archaeological significance in this data than the morning data.

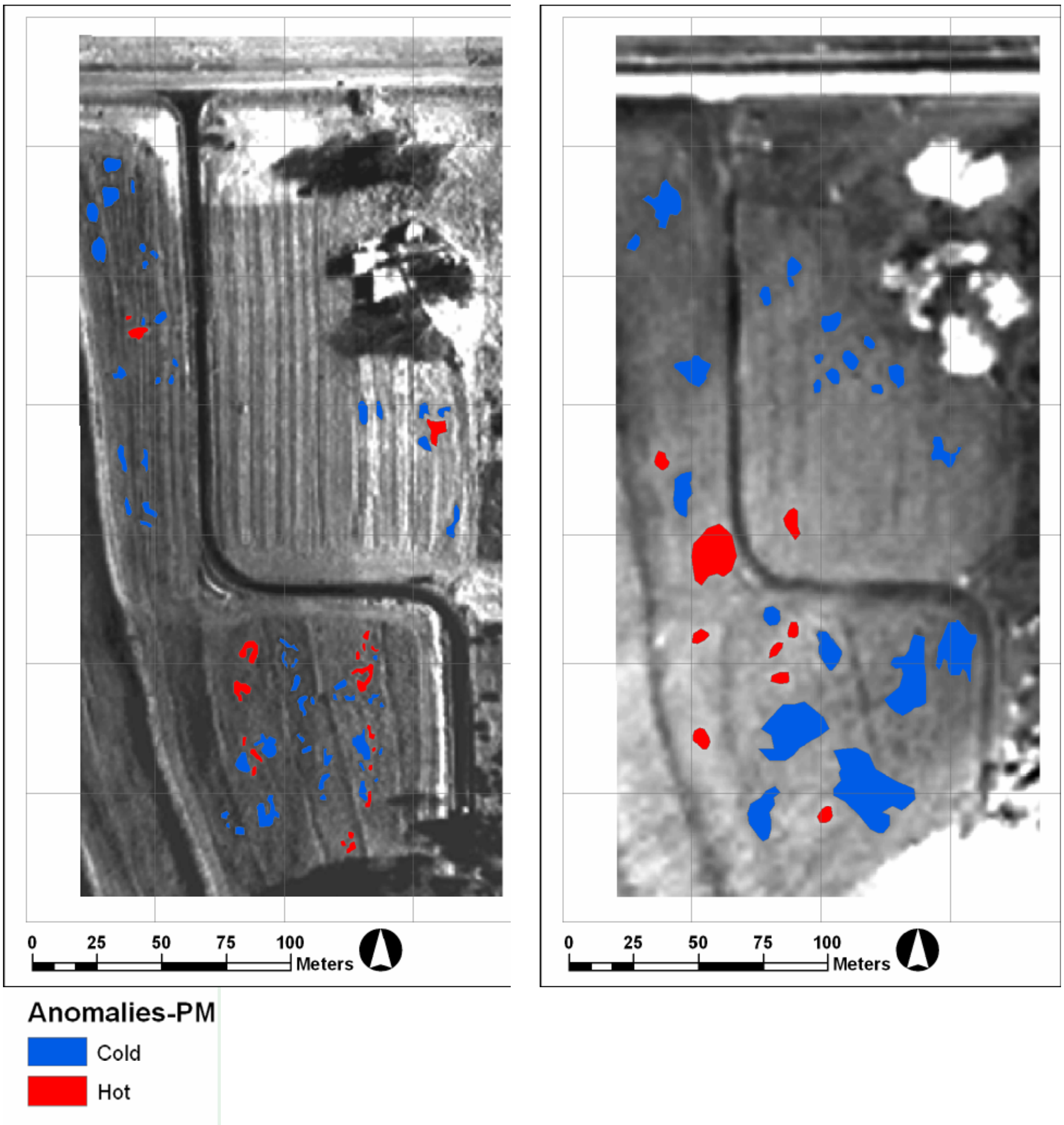


*Figure 4. Morning (left) and evening (right) thermal infrared composite images with anomalies identified.*

Anomalies were identified as hot or cold and coded on vector layers (Figure 4) for both data sets. Only anomalies that were not related to obvious surface features were included. Features such as stone foundations, characterized by low conductivity and low thermal inertia, should be visible as positive or hot targets in the morning and negative or cold targets in the evening. A pit is a type of anomaly that might show the converse thermal behavior (negative in the morning and positive in the evening).

The resulting geographic information system (GIS) of these data sets accompanied this analysis (but are omitted here). The GIS consists of two raster (the thermal infrared composites in Erdas Imagine format) and two vector (the interpretation polygons in ESRI shapefile format) files. In addition, an ArcMap document was included that contains all four of the data sets (but omitted here).

A series of oblique images were also collected, covering areas away from the site core. These areas were not included in the composite image since these down slope areas are heavily disturbed and the extreme oblique angle of these images. However, these images (omitted here) were also provided with this analysis to be used as reference.

**Conclusions**

The thermal infrared survey of New Philadelphia yielded a number of anomalies that may be related to the 19th century occupation of the site. Only subsurface testing can fully explain these. The success of the survey may be limited by the ground cover at the site. To give thermal infrared surveys the greatest chance for success, data should be collected in bare earth or, if that is not possible, the vegetation should be short and even across the survey area.

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**Observations on Methods for Testing the Thermal Infrared Survey Data**

Christopher Fennell

The results of the thermal infrared survey conducted in May 2008 by Bryan Haley and Tommy Hailey were partially investigated through ground-based excavation work in the Summer 2008 field school at New Philadelphia. A more systematic testing of the precise locations of the aerial thermal anomalies identified by Haley and Hailey will be undertaken in future field seasons through targeted ground-based geophysical surveys, soil core sample surveys, and excavations.

Examining the data results of identified thermal anomalies depicted in Figure 2.4 above and in GIS data images provided by Haley and Hailey, our excavation team has observed a number of instances in which the locations of thermal anomalies appear to correlate with the known locations of sub-surface foundation remains from past residences located within the town site. These correlations will be analyzed and tested further in upcoming field seasons.

Bryan Haley also served as a geophysical consultant with Time Team America's staff who investigated portions of Block 8 in July 2008 in a search for the foundation remains of a small school house that served African American children in New Philadelphia in the mid-1800s. In addition to testing various forms of ground-based geophysical surveys in Block 8, Haley also analyzed the thermal infrared data in that area and the Time Team archaeologists ground-tested promising locations with excavations. A report on the results of Time Team's work on Block 8 is provided in Chapter 5 of this report.

Our Summer 2008 field school participants also investigated an area of comparative data between ground-based geophysical surveys and the aerial thermal survey in the area platted as King Street along the north edge of Block 8. As discussed in Chapter 6 of this report, an electric resistivity survey conducted by Michael Hargrave showed a clear alignment of anomalies running east to west along the space of a side street within the town plan. This location was covered by a stone and gravel stretch of narrow roadway in a 1939 aerial photograph, but is today covered entirely in agricultural soils and vegetation, with no visible remains of the road on the ground surface. The thermal infrared survey did not produce data indicative of anomalies that would correlate with the space of such a roadbed. Excavations in the Summer of 2008 in a sampled space of the resistivity anomalies in King Street revealed a lens of gravel and stone from an early 1900s roadbed buried 1 foot below the current ground surface, and, beneath that, the remains of a late 1800s packed dirt roadway with wheel rut depressions. In comparing the thermal infrared data with the ground-based electric resistivity data, it is remarkable how clearly the remains of the road appear in resistivity survey results but not in the thermal infrared results. As we continue to investigate the thermal infrared anomalies in future field seasons, it may become clear that this aerial survey method is highly valuable and cost-effective for locating the buried remains of foundations to buildings, but cannot detect the more subtle remains of town infrastructure elements, such as buried roadbed remains.

**New Philadelphia Archaeology Reports:**
**http://www.anthro.uiuc.edu/faculty/cfennell/NP/reports.html**

**New Philadelphia Archaeology Project web site:**
**http://www.anthro.uiuc.edu/faculty/cfennell/NP/**