1. Project Summary

This project supported efforts to employ drone-acquired thermal and multispectral imagery in discovery, documentation, and interpretation of archaeological landscape features at sites in North America and the Middle East. Archaeologists have known since the 1970s that aerial thermal images could potentially reveal a wide range of ancient remains—including buried architecture, artifact concentrations, roads, fields, or earthworks—because these features retain and emit heat differently than surrounding soil. However, until recently technological hurdles made aerial thermography impractical to collect and difficult to process. Our previous work, supported by an NEH Digital Humanities Level II Start-Up grant, enabled us to develop some of the basic strategies for modern archaeological aerial thermography, bringing together a small drone, a lightweight thermal camera, and photogrammetry software.

This project builds on the success of our start-up project, experimenting with a new generation of radiometric thermal cameras and the integration of multispectral near-infrared sensors. We also employ dramatically improved drone technology and powerful new processing methods. These novel technologies were deployed in exploratory survey projects at many different archaeological sites situated in distinct environmental contexts, helping to reveal both the opportunities and challenges of drone-based thermal and multispectral imaging.

The project was based at the Spatial Archaeometry Lab (SPARCL) at Dartmouth College and directed by Prof. Jesse Casana. The project employed two postdoctoral fellows, Austin Chad Hill and Madeleine McLeester, one lab technician, Carolin Ferwerda, and included two Dartmouth graduate students, Elise J. Laugier and Jonathan Alperstein. This Dartmouth-based team collaborated with numerous other archaeologists in conducting field surveys, analyzing data, and publishing results. Collaborators included: Lisa Overholtzer (McGill University), Mark McCoy (Southern Methodist University), Thegn Ladefoged (University of Auckland), Kelsey Reese (University of Notre Dame), Mark Schurr (University of Notre Dame), Kevin Fisher (University of British Columbia), Donald Blakeslee (Wichita State University), and Michael O’Conner (Enfield Shaker Museum).

Results of the project have been published in a wide range of academic journal articles, presented at numerous professional conferences and public lectures, and received abundant media coverage in a range of popular venues (see appendix). Our ongoing work, supported by grants from other agencies and foundations, is continuing to develop our methods, experiment with new technologies, and undertake new archaeological investigations at different sites around the world.

2. Project Origins and Goals

The overarching goals of this project were to develop new methods for the discovery, mapping, and interpretation of ancient archaeological features, and to test them in a range of different archaeological sites and landscapes. Excavation is a slow, laborious, and destructive
process, while the handful of other technologies archaeologists use to see below the ground—
magnetometry, ground penetrating radar, or electrical resistivity—have changed little over the
past two decades. The potential to use drone-based thermal imaging to reveal subsurface
archaeological features holds enormous potential for the discipline, not only because it provides
a new method for revealing otherwise invisible features, but also because it can be collected so
rapidly over such large areas.

This project had its origins in an NEH Level II Digital Humanities Start-Up grant, for a project
we undertook from 2012-2014 when the project director was still a faculty member at the
University of Arkansas. At that time, consumer-grade drones capable of mapping small areas of
the ground were still relatively newly available to researchers. Our project used an early model of
such a drone to deploy one of the first ultralight, uncooled thermal cameras that was also available
for public purchase. The images we collected with it, as an analog video feed, were then
processed using the first generation of now ubiquitous digital photogrammetry software. Although
by contemporary standards a decade later, the technologies we employed in this initial project
appear rudimentary at best, we managed to undertake several successful surveys, with the best
results from an ancestral Puebloan settlement in New Mexico (Casana et al. 2014). Other surveys
including at the Mississippian center of Cahokia, Illinois, the Late Bronze Age site of Kalavasos
Ayios Dimetrios in Cyprus, and a mound center in northwest Arkansas, all yielded some data but
mostly revealed the limitations of thermal imaging in certain contexts (Casana et al. 2017).

Following the project director’s move to Dartmouth, the current project, funded by an NEH
Digital Advancement Grant (2017-2021), sought to build on our results from the Start-Up grant,
using improved camera and drone technologies and more advanced processing techniques to
conduct an expanded series of investigations. In particular, a new generation of “radiometric”
thermal cameras had become available that promised to provide far more accurate and nuanced
thermal imagery, while at the same time, new sensors were available that could produce
multispectral images in the visible and near infrared light spectra. These technologies could also
now be deployed on much more reliable and powerful drones, and the data could be seamlessly
processed in advanced photogrammetry software.

We sought to deploy these new technologies at a range of different archaeological sites,
representing different types of ancient settlements, with variable preservation, located in distinct
environments. As such, our hopes were to produce nuanced insights into the contexts in which
archaeological aerial thermography would be most successful as well as developing strategies
for making the most of this method in challenging circumstances. We also hoped to discover new
features or details of the ancient settlements at which we undertook surveys, yielding a range of
novel observations about the past inhabitants of these places and helping to frame new research
questions going forward.

3. Project Activities, Team, & Participants

Core activities of this project involved acquisition of instrumentation, development of a
field deployable method for thermal imagery collection in archaeological contexts, and
experimentation with thermal and multispectral surveys on collaborative archaeological projects.
Technology Development

Over the course of the project, all of the technologies we were using continued to be improved upon as the pace of development in the drone industry has been stunning. As such, we continually adapted our methods and acquired new instrumentation to stay current with technology. For example, at the start of the project in 2017, we purchased the newly available thermal camera from FLIR, the Vue Pro-R, which is a very small, lightweight camera designed for drone deployment. However, after experimentation with the system, we upgraded it using a third-party device meant to minimize the “drift” in thermal data values it collects over time. We then upgraded the camera a third time to a new FLIR sensor, this time designed to be fully integrated into new drone hardware. Similarly, our initial surveys as part of this project were undertaken using the 3DR Solo, a consumer-grade quad-copter drone. However, 3DR then declared bankruptcy and discontinued their drone production, such that within two years navigation software and other devices no longer supported them. We therefore switched our approach to use the industry leading DJI Phantom 4 Pro, but it is difficult to outfit these drones with third party cameras, requiring extensive engineering in our lab to mount and power the cameras on this otherwise very capable drone. Then, in 2019, we upgraded again to the DJI Matrice 210 RTK, a drone that would enable cameras to be mounted directly, and which would eliminate the need for laborious ground control point collection. These examples illustrate the necessity for us to adapt our plans in order to keep pace with fast moving technological developments in drones, cameras, and software.

Field Surveys: Plans and Challenges

At the outset of our project, we had planned to conduct surveys in a select number of sites in a variety of distinct environments. But as with our technological development, we had to alter our plans for field surveys continuously due to a variety of factors beyond our control. As we had already learned the hard way, thermal surveys are highly sensitive to ground conditions and so must be undertaken under optimal seasonal conditions. It proved challenging to schedule some of our more far-flung planned projects because of this fact. In other cases, local regulations regarding drone flights changed during the course of the project, such that in Iraq our equipment was seized by customs officials, in Mexico we had to pay considerable fees to get equipment into the country, while in Jordan surveys were simply not allowed to take place. In the US, surveys in Hawaii required us to become FAA certified pilots, a new administrative tool at the time, while new regulations prohibited drone flights in National Parks and sometimes in National Forests as well.

All of these and other factors required us to continually adapt our fieldwork plans, sometimes forgoing surveys we had hoped to undertake, but always looking for new opportunities to replace them. Ultimately, we were able to undertake many successful surveys at many sites around the world, leading to numerous productive and ongoing collaborations. Successful surveys included work on the Big Island, Hawaii, at Mesa Verde, Colorado, in Tlaxcala, Mexico, at various sites in Garmian Province, Kurdistan Region of Iraq, Enfield Shaker Village, New Hampshire, at Etzanoa, Kansas, in Midewin National Tallgrass Prairie, Illinois, on the Menominee Indian Reservation, Wisconsin, and at Harkdale Farm, Vermont.
**Project Team Members (Dartmouth College)**
Director: Prof. Jesse Casana
Postdoctoral Fellow: Austin Chad Hill (2017-2019)
Postdoctoral Fellow: Madeleine McLeester (2020-2021)
Research Associate: Carolin Ferwerda (2017-2021)
Graduate Student: Elise J. Laugier (2017-2020)
Graduate Student: Jonathan Alperstein (2020-2021)

**Collaborators**
Lisa Overholtzer (McGill University)
Mark McCoy (Southern Methodist University)
Thegn Ladevedeg (University of Auckland)
Kelsey Reese (University of Notre Dame)
Mark Schurr (University of Notre Dame)
Kevin Fisher (University of British Columbia)
Donald Blakeslee (Wichita State University)
Michael O’Conner (Enfield Shaker Museum)

**4. Project Outcomes**
This project supported efforts to employ drone-acquired thermal and multispectral imagery in discovery, documentation, and interpretation of archaeological landscape features at sites in North America and the Middle East. Over the several years of the project, we continually upgraded the technology we were employing in the rapidly changing landscape of drones and sensors. We were also able to experiment with thermal and multispectral imaging at many sites in different parts of the world, including in North America in the Northeast, the Colorado Plateau, and the Great Plains, in highland Mexico, on the Big Island of Hawaii, as well as in the Kurdistan Region of Iraq. Results of the project have been published in a series of academic papers in several top archaeology and remote sensing journals, as well as being reported on in many mainstream media outlets (see appendix). The project has successfully developed powerful new methods that have made significant discoveries at many sites we surveyed, as well as demonstrating to scholars and heritage professionals around the world the potential of aerial thermal imaging in archaeological research.

In addition to developing new methods and technologies, we also made very significant discoveries at numerous sites, helping to transform our understanding of the settlement history and possibilities for preservation at them. For example, in our survey at Midewin National Tallgrass Prairie, Illinois, we found evidence of both previously undocumented house basins as well as a ritual enclosure at the site (McLeester et al. 2018). Similarly, in our survey at Etzanoa, Kansas, the possible location of a once large ancestral Wichita settlement, we found a very large circular earthwork that was previously unknown at the site (Casana et al. 2020). In our surveys at the Enfield Shaker Village, New England, we located extensive remains of nineteenth century buildings and other subterranean features (Hill et al. 2019), while in the Kurdistan Region of Iraq, we found evidence of ancient field boundaries and waterways surrounding long-lived sites (Laugier and Casana, in press).
Beyond archaeology, results of the project have proven to be of significant interest to a range of remote sensing-oriented researchers in other disciplines, including ecology, geology, and environmental studies. Our methods have also been adapted to more practical domains, including locating buried infrastructure and unexploded ordinance in conflict zones, and many other such applications are possible, with our publications serving as a key reference for scholars across a range of disciplines.

In addition, we have developed a range of classroom-based activities for teaching and learning at the undergraduate level. A series of lab exercises using thermal imagery collected by the project have been developed and tested in courses at Dartmouth, and will soon be published along with other materials for use by other educators around the country. A planned 2-day workshop sponsored by the National Park Service had also been scheduled for June 2020, and would have provided an opportunity for archaeologists and heritage professionals to learn about thermal imaging firsthand, but the program has been repeatedly delayed due to the pandemic.

Finally, the results of the project at various stages have received widespread media coverage, helping to broaden the impact of our work and reach very large audiences of the interested public. Our results and work have been featured in the New York Times, The Washington Post, US News & World Report, ABC News, Atlas Obscura, Ars Technica, Science News and elsewhere.

5. Project Evaluation and Impact

We did not employ a systematic method for evaluation of project performance, given the small size of our team and the nature of the work we were undertaking. However, we feel that the steady production of high-profile, peer-reviewed journal articles reporting on our results alongside an active program of public and professional presentations are the most important measures of success and impact.

6. Project Continuation and Long-Term Impact

Results of this project have had significant impacts on archaeology, transforming aerial thermal imaging from a little-known technique to a widely accepted approach in mapping archaeological landscapes. The basic set of investigative methods and analytic approaches we developed in this project have become a cornerstone for a wide range of multi-sensor remote sensing technologies in archaeology. We anticipate a growing interest in archaeological aerial thermography in the coming years, with many applications by scholars at sites around the globe.

Our research in these areas is continuing, with initiatives funded by other agencies and foundations that build upon and leverage the expertise and technologies developed during the NEH project. For example, in 2019 we received funding the Neukom Institute for Computational Science to acquire a drone-deployable lidar sensor, and with funding from the National Science Foundation’s Archaeometry program, we have now deployed the lidar alongside thermal and multispectral imaging at several sites, including in Hawaii, Mesa Verde, Colorado, and in New Hampshire. Similarly, in 2020 we received a new grant from the NASA Space Archaeology program to develop drone-based surveys of archaeological sites using a short-wave infrared (SWIR) sensor, essentially filling the spectral void between the thermal and NIR experiments funded by NEH. Finally, through a continuing grant from the National Science Foundation's
Archaeometry Program, my lab is the site of the Spatial Archaeometry Research Collaborations (SPARC) initiative: https://sites.dartmouth.edu/sparcl/sparc-grants/

Archaeologists apply to the program, and if successful, they receive in-kind collaborative support for research projects using a range of geospatial technologies. Our expertise and equipment in thermal imaging has already proven in demand, and we have several new projects using the technologies planned for the coming year already. We are grateful for the generous support of the NEH Digital Humanities for our research.
APPENDIX: PRODUCTS

Publications


Conference Presentations and Invited Lectures


Jesse Casana “Mapping archaeological landscapes using drone-acquired lidar,” Remote^2@Dartmouth, (December 2020)

Adam Johnson, Mark McCoy, Austin Chad Hill, Jesse Casana and Thegn Ladefoged, “Expanding our remote sensing toolkit: The first application of UAV aerial thermography in the Hawaiian Islands,” Society for American Archaeology Annual Meeting, Albuquerque, NM (April 2019)

Jesse Casana, “Exploring Archaeological Landscapes using Aerial Thermal Imaging” Light@Dartmouth Symposium, sponsored by the Neukom Institute (February 2019)

Jesse Casana, Elise Laugier, and Austin Chad Hill “Archaeological Prospection using Drone-acquired Thermal and Multipsectral Imagery” Computer Applications in Archaeology Annual Meeting, Tubingen, Germany (March 2018)


Media Coverage

Podcast: “Drones Revealing the Past—Jesse Casana,” Parsing Science (December 15, 2020) [online]

Chernick, Karen, “How Drones Help Archaeologists Peer into the Earth,” Atlas Obscura (October 9, 2020) [online]

Bower, Bruce, “Drones find signs of a Native American ‘Great Settlement’ beneath a Kansas pasture,” Science News (Sept. 10, 2020) [online]

Smith, Kiona, “Archaeologists with drones discover pre-Columbian earthworks in Kansas,” Ars Technica (Sept. 11, 2020) [online]

Brooks, David, “N.H. Archaeologists use drones, heat vision to scope out sites,” Concord Monitor (Oct. 24, 2017) online