NEH Application Cover Sheet
Humanities Collections and Reference Resources

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Field of Expertise: Archaeology

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APPLICATION INFORMATION

Title: *The CORONA Atlas Project: Correction and distribution of declassified satellite imagery for archaeological research.*

Grant Period: From 5/2013 to 5/2016

Field of Project: Archaeology

Description of Project: This project seeks funding to expand an online database of declassified, Cold
War-era CORONA satellite imagery, collected as part of the world???s first intelligence satellite imaging program from 1960-1972. These unique images, made publicly available in 1996, have proven to be a critical resource in archaeology, primarily because they preserve a picture of sites and landscapes that predates recent agricultural, industrial and urban development. Such land use changes have often resulted in archaeological features being obscured or destroyed, and CORONA is therefore a truly unique resource, enabling archaeologists to reconstruct and virtually explore lost landscapes. Research in

BUDGET

Outright Request	$312,373.00	**Cost Sharing**	$137,444.00
Matching Request	$0.00	**Total Budget**	$449,817.00
Total NEH	$312,373.00		

GRANT ADMINISTRATOR

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The CORONA Atlas Project: Correction and distribution of declassified satellite imagery for archaeological research

This project seeks funding to expand an online database of declassified, Cold War-era CORONA satellite imagery, collected as part of the world's first intelligence satellite imaging program from 1960-1972. These unique images, made publicly available in 1996, have proven to be a critical resource in archaeology, primarily because they preserve a picture of sites and landscapes that predates recent agricultural, industrial and urban development. Such land use changes have often resulted in archaeological features being obscured or destroyed, and CORONA is therefore a truly unique resource, enabling archaeologists to reconstruct and virtually explore lost landscapes. Research in the Near East, where CORONA has been most extensively utilized, shows its potential as a tool for the discovery and mapping of archaeological sites, the documentation of associated roads, canals and field systems, and the reconstruction of ancient landscapes. Despite the proven value of CORONA imagery in archaeology, difficulties involved in the geometric correction of raw images have hindered its widespread use by archaeologists. While digital scans of CORONA images can be purchased and downloaded through the USGS, these uncorrected images contain extreme spatial distortions created by the satellites' unusual panoramic cameras. No commercial software packages are currently able to geometrically correct CORONA images, and without doing so, images cannot be used in mapping or GIS applications.

Our recent research, funded by a previous NEH grant ("CORONA Archaeological Atlas of the Middle East" PW-50083-08), successfully developed a method for efficient and accurate geometric correction of CORONA imagery. We used these techniques to correct more than 1200 images from across the Near East, and we are now distributing the images through a custom-built website: http://corona.cast.uark.edu/index.html Archaeologists and other researchers can view, export and download CORONA imagery with ease. We also provide tools to compare 1960s images with the modern landscape, basic measurement functions, a database of major archaeological sites in the region, and tutorials for more advanced applications such as stereo analysis and topographic data extraction.

The success and popularity of our project to develop a Near Eastern CORONA imagery atlas, combined with interest from scholars working in many other parts of the world, has led us to seek support for expansion of the project to other regions. We aim to use the techniques we have developed for correction and distribution of CORONA to create similar imagery databases for parts of the world where the imagery will likely have great value to archaeologists and other researchers. We plan to correct approximately 3000 stereo images, focusing on five regions: central and eastern China, southeastern Europe, central Asia, the Indus Valley, and the African Sahel. Once completed, the project will make historic CORONA images and the tools to deploy them available to researchers in key regions across the globe. Our experiences in creating the existing Near Eastern CORONA atlas leads us to believe there will be significant interest in the imagery, and that the data will reveal a rich archaeological landscape that remains largely undocumented by modern scholarship.

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SIGNIFICANCE

Overview

This project seeks funding to expand an online database of declassified, ColdWar-era CORONA satellite imagery, collected as part of the world's first intelligence satellite imaging program from 1960-1972 (Day et al. 1998). These unique images, made publicly available in 1996, have proven to be a critical resource in archaeology, primarily because they preserve a picture of sites and landscapes that predates recent agricultural, industrial and urban development. Such land use changes have often resulted in archaeological features being obscured or destroyed, and CORONA is therefore a truly unique resource, enabling archaeologists to reconstruct and virtually explore lost landscapes. Research in the Near East, where CORONA has been most extensively utilized, shows its potential as a tool for the discovery and mapping of archaeological sites, the documentation of associated roads, canals and field systems, and the reconstruction of ancient landscapes (e.g., Kennedy 1998; Challis et al. 2002-4; Ur 2003, 2005, 2010; Casana 2003, 2007; Casana et al. 2012; Beck et al. 2007). Despite the proven value of CORONA imagery in archaeology, difficulties involved in the geometric correction of raw images have hindered its widespread use by archaeologists. While digital scans of CORONA images can be purchased and downloaded through the USGS, these uncorrected images contain extreme spatial distortions created by the satellites' unusual panoramic cameras (Altmaier and Kany 2002; Casana and Cothren 2008). No commercial software packages are currently able to geometrically correct CORONA images, and without doing so, images cannot be used in mapping or GIS applications.

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The success and popularity of our project to develop a Near Eastern CORONA imagery atlas, combined with interest from scholars working in many other parts of the world, has led us to seek support for expansion of the project to other regions. We aim to use the techniques we have developed for correction and distribution of CORONA to create similar imagery databases for parts of the world where the imagery will likely have great value to archaeologists and other researchers. We plan to correct approximately 3000 stereo images, focusing on five regions: central and eastern China, southeastern Europe, central Asia, the Indus Valley, and the African Sahel. Once completed, the project will make historic CORONA images and the tools to deploy them available to researchers in key regions across the globe. Our experiences in creating the existing Near Eastern CORONA atlas leads us to believe there will be significant interest in the imagery, and that the data will reveal a rich archaeological landscape that remains largely undocumented by modern scholarship.

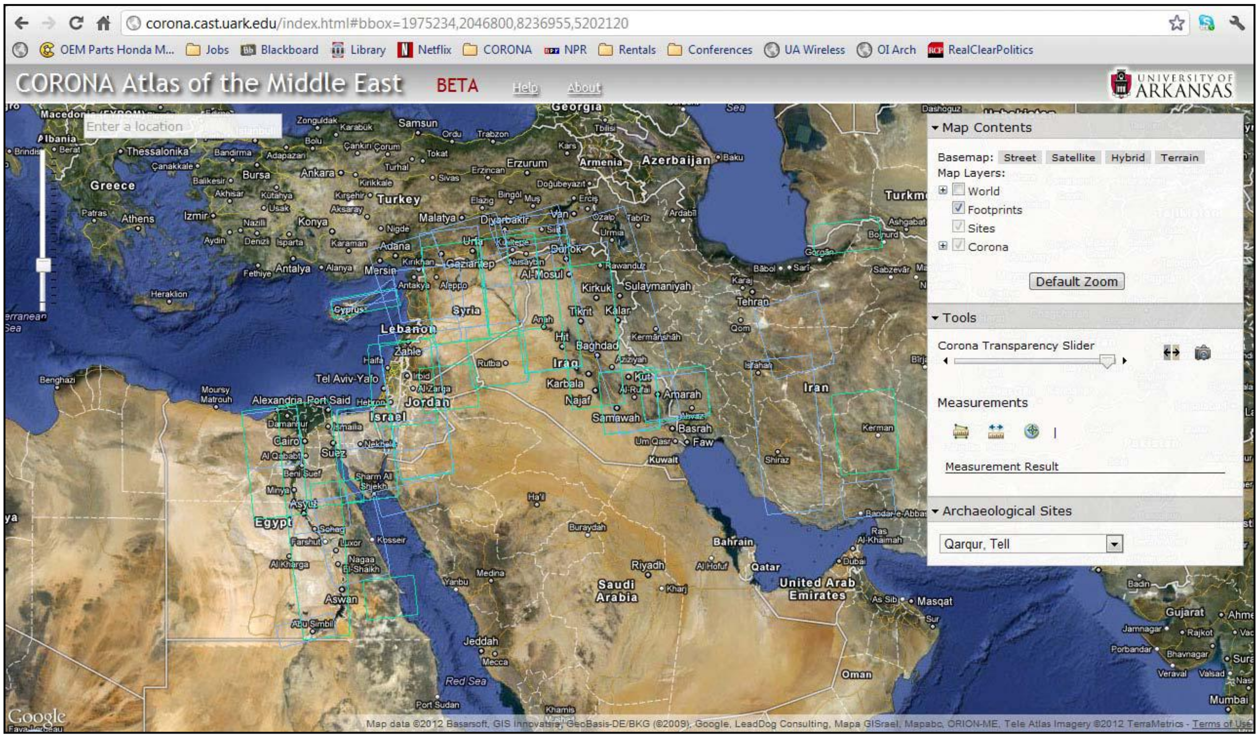

Figure 1: Screen capture from the CORONA Atlas of the Middle East.

Archaeology from the Air

Since the pioneering studies of O.G.S. Crawford (1923, 1929; Crawford and Keiller 1928) and other scholars (e.g., Beazeley 1919; Poidebard 1934; Reeves 1936)archaeologists have recognized the phenomenal power of aerial images to aid in the discovery of sites and the recognition of ancient landscape features including roads, field systems, and earthworks (e.g., Wilson 2000; Bewley and Raczkowski 2000). A vertical perspective on the landscape often reveals features that are nearly impossible to recognize on the ground. Areas of ancient settlement may appear as differently colored soils, while faint traces of now buried walls, roads or other alignments can often be detected as well. Today the integration of such imagery in archaeological research is standard practice as the ability to quickly recognize ancient settlements and associated cultural features at a regional scale is essential to studies of ancient landscapes.

The conventional, black-and-white aerial photographs used by earlier generations of archaeologists have now been largely replaced by reliance on high-resolution, commercial satellite imagery such as Quickbird, Ikonos and GeoEye (e.g., Alexakis et al. 2009; Cavalli et al. 2007; De Laet et al. 2007; Due Trier et al. 2009; Lasaponara and Masini 2007; Pryce and Abrams 2010; Salvi et al. 2011). Some scholars even utilize imagery acquired by aircraft equipped with specialized sensors capable of detecting wavelengths across the light spectrum (e.g., Challis et al. 2009) or mapping topographic features below forest canopies (Devereux et al. 2008; Chase et al. 2011; Bewley et al. 2006). While images acquired by these advanced sensors can be powerful tools in archaeology, their high costs, ranging from several thousand dollars for individual archived satellite images to hundreds of thousands for specially-tasked aircraft, makes them beyond the reach of most archaeologists. Even more critically, the ancient landscape archaeologists seek to investigate has often been heavily impacted by modern land use practices. The spiraling population of urban centers has covered archaeological remains with sprawl. The institution of intensive, industrialized agricultural regimes has obscured or destroyed many sites through earthmoving, irrigation works, and other processes. The creation of massive reservoirs along river valleys—places that were foci of settlement throughout human history—has flooded countless sites below rising waters. The combined effects of these and other recent land use changes seen throughout much of the world has been devastating to the archaeological record, meaning that modern aerial and satellite imagery, even at very high spatial and spectral resolution, will reveal only a fraction of the sites and features that were extant a few decades ago.

In order to address the problem posed by recent land use changes, archaeologists have increasingly turned to analysis of historic aerial photographs from the early and mid-20th century, acquired variously by national mapping programs, agricultural monitoring or military intelligence missions. In studies ranging from the eastern Mediterranean (Turner and Crow 2010; Bescoby 2006), to northern Europe (Stichelbaut 2006), to the US Great Plains (Johnson 2005), these historic images have proven to be very valuable in that they preserve a picture of archaeological sites and features that today are obscured or altogether destroyed by industrial and urban development. However, even when such photos can be located, they often cover only small areas in a non-systematic manner. The original films on which images were acquired have often deteriorated, and much of the associated information required to integrate images into modern GIS applications, such as camera focal length and average flying height, are unknown. Most importantly, in much of the world, historic aerial photographs are inaccessible to archaeologists because they are regarded as militarily sensitive by modern nations; in other cases, they are simply non-existent.

The CORONA Revolution in the Near East

In part thanks to the lobbying efforts of Mesopotamian archaeologist and then- Secretary of the Smithsonian Robert McCormick Adams, President Clinton in 1995 signed an executive order directing the declassification of photographic imagery acquired by the first generation of United States spy satellites, a system code-named CORONA (Day et al. 1998; McDonald 1995). The archive consists of more than 860,000 satellite images covering much of the world, dating from 1960-1972. The latest generation of CORONA imagery from the KH-4B missions, dating from 1967-1972, offers high spatial resolution (1.83m), allowing archaeological sites and features to be seen with great clarity in the best images (Fig.2). Moreover, CORONA images were taken in stereo, so that the relief of the ground surface can be viewed in three dimensions, and it is possible to extract digital elevation data or topographic maps directly from the imagery (Altmaier and Kany 2002; Gheyel et al. 2004; Goossens et al. 2006; Casana and Cothren 2008; Casana et al. 2012; Galiatsatos et al. 2011).

The potential of CORONA imagery for archaeology was quickly recognized by researchers working in the Near East, where conventional aerial photographs are rare or inaccessible (e.g., Kennedy 1998; Kouchoukos 2001; Philip et al., 2002, 2005; Challis et al. 2002-2004; Ur 2002, 2003, 2005, 2010; Casana 2003, 2007, 2008; Casana and Wilkinson 2005; Casana et al. 2012; Fowler 2004; Altaweel 2005; Wilkinson et al. 2006; Pournelle 2007; Beck et al. 2007; Hritz 2010). In that region, CORONA imagery has proven to be an extremely powerful tool, preserving a picture of countless sites and features that have today been obscured or completed destroyed by modern land use (Fig.3). Since the late 1990s, CORONA imagery has facilitated the discovery of hundreds of previously unrecorded sites, transformed our understanding of many previously known sites, and enabled us to recognize and map complex archaeological landscape features including ancient roadways, field systems and canals.

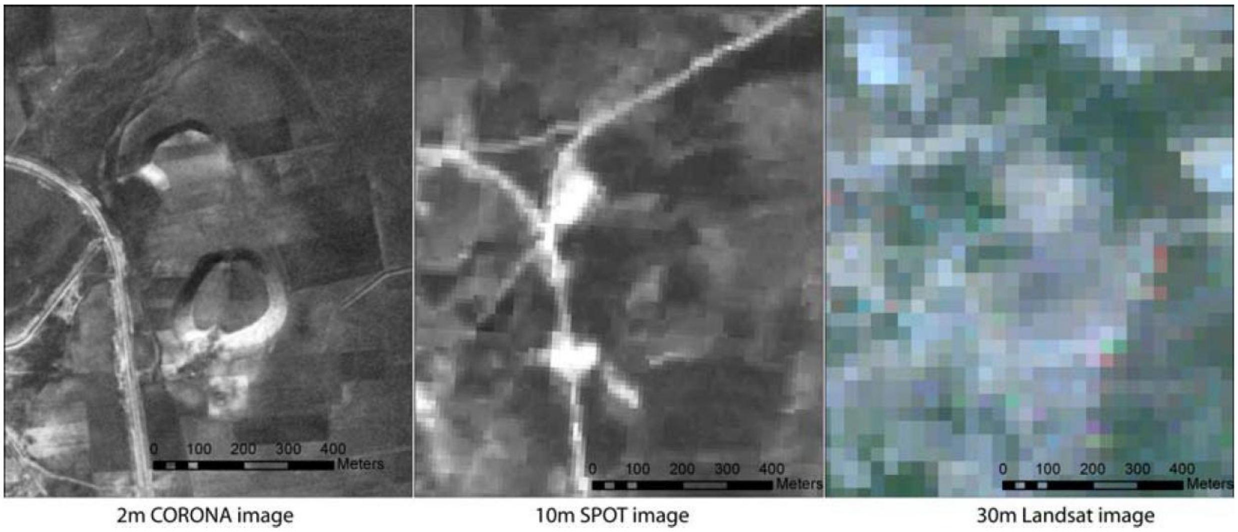

Figure 2: Resolution of a CORONA image of Tel l Qarqur, an archaeological site in western Syria, compared to lower resolution civilian satellite imagery.

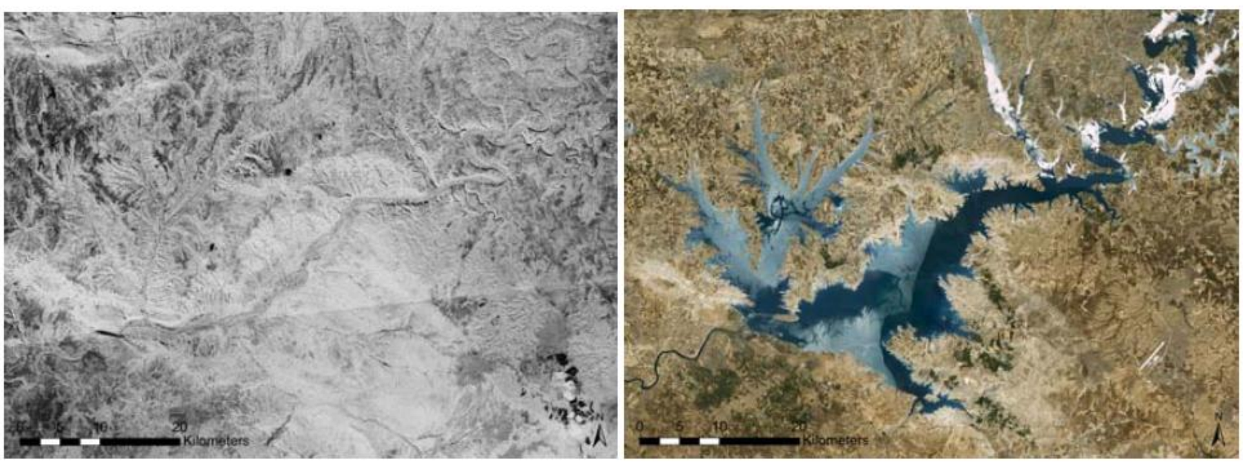

Figure 3: Area inundated by the Ataturk Dam in central Turkey on a 1968 CORONA image (left) and modern Google-served imagery (right). Thousands of archaeological sites have been submerged by dam projects in the Near East in recent decades.

Archaeological Site Discovery

Perhaps the most immediate value of CORONA imagery has been in its aid to regional archaeological surveys, revealing countless undocumented sites (Fig. 4). In some areas of the Near East, such as the plains of northern Mesopotamia in the region known as the Jazireh, intensive surveys conducted over the past decade with the aid of CORONA imagery have found that virtually all significant archaeological sites are visible in the best scenes (Ur 2002, 2010; Wright et al. 2007). These surveys increased site discovery by a factor of four or five compared to earlier projects (e.g., Eidem and Warburton 1996). In the Amuq Plain of southern Turkey (Casana and Wilkinson 2005) and the Homs area of western Syria (Beck et al. 2007; Philip et al.

2002), CORONA is less of a panacea owing to more complex topography, geology and other factors, but it nonetheless increased site discovery rates substantially. In the Amuq Plain, more than 100 previously unrecorded sites were documented on CORONA, despite years of earlier survey work) in the region (Braidwood 1937; Yener et al. 2000), revolutionizing our understanding of the area's settlement history (Casana and Wilkinson 2005; Casana 2007).

Most survey projects in the Near East did not have access to CORONA or other aerial imagery, but the large new database of CORONA we have created now makes it possible to virtually re-survey older projects. Our own current NASA-funded research project takes advantage CORONA imagery generated through the NEH CORONA Atlas to evaluate settlement history across a 300,000 sq km region in the Northern Fertile Crescent by systematically documenting all visible sites. Analysis of 35 previously published surveys often reveals the richness and complexity of archaeological landscapes that went unrecorded by earlier researchers. For example, in the Qoueiq River Valley north of Aleppo, Syria, a survey project in the late 1970s attempted to record as many sites as possible (Matthers 1981), but low-intensity methods inevitably missed many sites and features in the region. Dozens of sites can be seen on CORONA imagery between those ones discovered and mapped by the project, highlighting how little we may know about settlement history in many parts of the Near East.

Figure 4: Thousands of archaeological sites, such as Araban Hoyuki in southern Turkey (shown above), have never been recorded by Archaeologists, but often appear clearly on CORONA imagery.

Even at sites that were recorded, much can be learned through analysis of CORONA. For example, the Qoueiq survey includes the major mounded site of Tell Rifa'at, almost certainly the ancient city of Arpad, well-known as one of the pre-eminent powers of the region during the Iron Age in the early first millennium BC. While Rifa'at was recorded by the Qouieq survey and briefly excavated, the existence of a massive lower city surrounding the high citadel at the center of the site went undocumented (Fig.5). This lower town, demarcated by a near-perfectly circular fortification wall enclosing some 120 hectares, has now been largely obscured by the modern town, but its recognition on CORONA reveals that the ancient city of Arpad was perhaps the largest pre-Classical city in the Levant. Lower towns like that at Tell Rifa'at have now been recorded at dozens of sites across the study area (Casana et al. 2012).

Figure 5: Tell Rifa'at in western Syria where a massive, circular fortification wall surrounding the ancient citadel is visible on CORONA imagery, now covered by the modern city.

Ancient Landscape Features

In addition to sites themselves, one of the most valuable applications for CORONA imagery has been in discovery and documentation of larger cultural landscape features such as ancient roads, field systems, canal networks and earthworks. These features are quite vulnerable to destruction by modern land use owing to the fact that they are often difficult to recognize on the ground—being preserved only as slight soil discolorations or subtle topographic depressions—and are rarely protected by national antiquities authorities. Fortunately CORONA imagery preserves a picture of such features, and has led to remarkable discoveries across the Near East. For example, the distinctive systems of radial roadways surrounding mounded sites across the northern Mesopotamian plains have been well documented using CORONA imagery (Ur 2003, 2009), although many of these features have now been erased or obscured by modern land use. Most previous research has concluded that these ancient roads, preserved only as subtle depressions in the landscape, are almost exclusively associated with settlements of the third millennium BC, as at Tell Brak (Fig.6), and located entirely within a narrow zone through eastern Syria and northern Iraq. Our recent analysis of regional-scale CORONA imagery has now documented very similar features across a much larger region, from the eastern Mediterranean to southwestern Iran and associated with sites of much later periods (Casana, forthcoming).

Throughout much of the Mediterranean basin, remains of Roman centuriated field boundaries, typically preserved as rectilinear stone clearance walls or other similar features, can be detected on historic aerial imagery (Bescoby 2006; Casana, in press). CORONA images of the northern Levant reveal many remnants of Roman fields, most commonly in areas of rocky, marginally-productive soils where later agriculture was relatively modest. Good examples of such features have been documented in survey projects as in the Homs region of western Syria (Philip and Bradbury 2010), but are found over much larger region, as in the basaltic uplands of the Syrian-Jordanian border. Here extensive systems of rectilinear Roman period field walls are preserved in CORONA imagery, although many are now destroyed by bulldozing (Fig. 7).

Figure 6: Radial route systems at Tell Brak in eastern Syria are clearly visible on CORONA imagery, but have been largely obscured by modern agriculture, as seen in this comparison image from the CORONA Atlas.

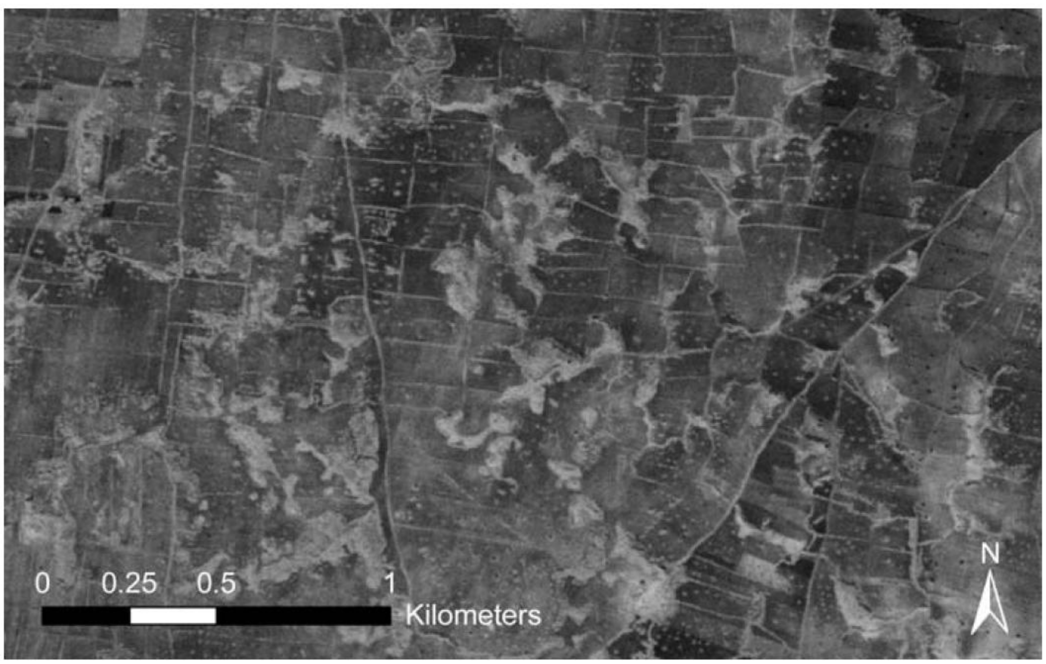

Figure 7: Rectilinear field boundaries are remnant elements of Roman cenuriated fields from the first and second centuries AD, preserved through the 1960s as stone clearance walls.

Ancient canals and other watercourses also often appear with striking clarity on CORONA imagery, making it an extremely useful tool for discovery, mapping and interpretation of these features. Extraordinarily complex canal systems have been documented throughout southern Mesopotamia (Hritz 2010), where virtually all agriculture depended on irrigation works and where large cities with dense populations have thrived for more than 6000 years. The longevity of settlement in this region and the history of repeated canal construction has left an amazing patchwork of overlapping systems visible at the surface—a classic archaeological palimpsest (Wilkinson 2003). In areas of less continuous irrigation, as in the plains of Khuzistan in southwestern Iran, remnants of canals networks are more intelligible. Well-preserved on CORONA imagery, these canals form regular, rectilinear networks (Fig. 8). Today however, most of these features have been destroyed by plain leveling operations (Alidazeh et al. 2004; Kouchoukos 2001).

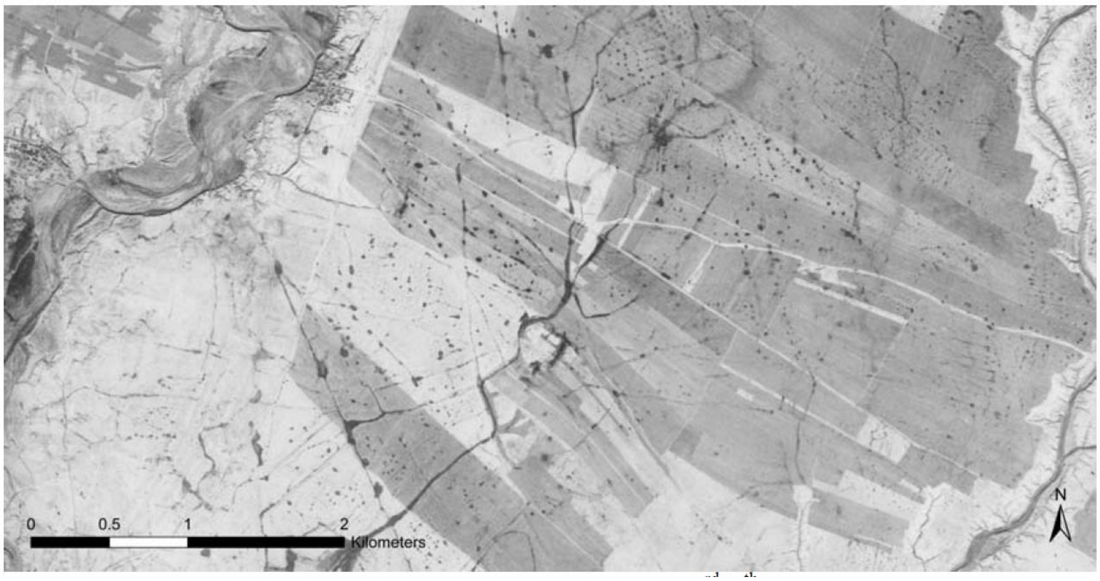

Figure 8: Dark linear features are remains of a Sasanian (3rd-6th century AD) canal system in Khuzistan in southwestern Iran. Today the region has been leveled for modern irrigation works.

Reconstructing Lost Landscapes in 3D

One of the most powerful but still underutilized possibilities for analysis of CORONA imagery involves taking advantage of its stereo capabilities. CORONA were captured by two cameras with a 30 degree separation, with the intention of using these images to map topography of areas being spied upon. Today, the laborious task of tracing contours from stereo images, something once only undertaken by trained specialists, can be accomplished using a variety of photogrammetry software packages, such as ERDAS' Leica Photogrammetry Suite. The high quality, rigorous rectification methods we employ enable imagery to be easily imported into such software packages, offering the possibility to extract high-resolution digital elevation data (Fig. 9) and to view images in 3D. Stereo analysis offers many possibilities for archaeological research, as seen, for example, in our work on the Euphrates River Valley of Syria. Here, a modern reservoir formed by the Tabqa Dam has submerged a vast region of the floodplain, but CORONA imagery from the 1960s enables us to reconstruct the topography of the plain and to map individual sites within it (Casana and Cothren 2008; Casana et al. 2012). The ability to document sites and landscapes in 3D offers enormous potential for similar analysis in areas impacted by reservoir construction, plain leveling operations undertaken as part of irrigation works, or sites that have been damaged through looting and bulldozing.

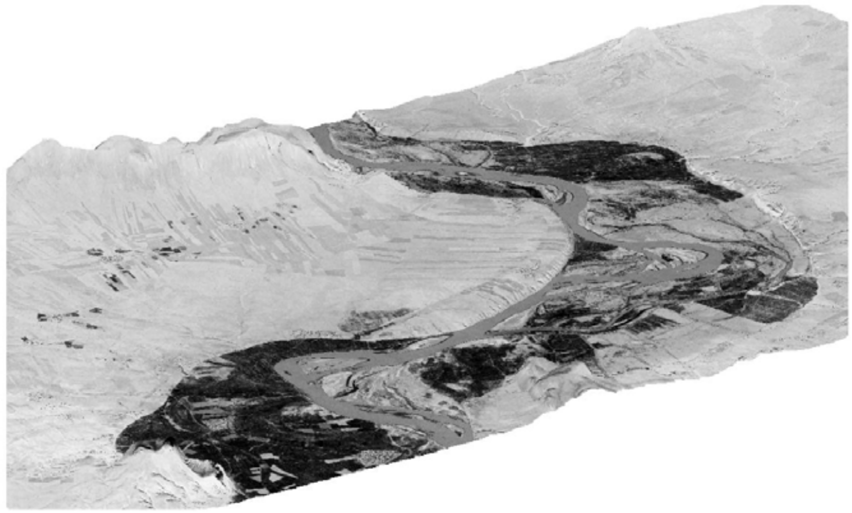

Figure 9: A digital elevation model with CORONA image draped over it from an area of the Euphrates River in Syria now inundated by Lake Assad.

Correcting Distortions in CORONA

While the value of CORONA imagery is now widely recognized by archaeologists, particularly in the Near East, raw, unprocessed images contain extreme spatial distortions that make it challenging to create maps from the images, to view them in GIS software, or to integrate them with other spatial datasets. The difficulties involved in geometric correction of CORONA images have effectively prevented the widespread use of the resource outside of a small cadre of remote sensing-oriented archaeologists. Our recent NEH-funded project succeeding in developing more efficient means of correcting CORONA images and distributing them via our custom built mapping website.

CORONA images were taken by a panoramic camera on elongated film strips, a system developed to maximize both the area that could be covered in a single frame and the resolution of the final image (Fig.10). In the highest resolution CORONA images, produced by the KH-4B generation of satellites in operation from 1967-72, the area covered by each film strip is approximately 13.8x188km, but the imaging geometry of the camera and the surface of the earth result in a "bow tie" area of the ground being stretched into the rectangular area of the film. Furthermore, the image motion compensators built into the imaging system did not fully account for the satellites motion during the image scan, which creates an "S" shaped pattern of distortion from one side of the image to the other. A third source of image distortion is derived from the topography of the ground as the parallax changes between the ground and the imaging surface inside the camera. In an attempt to capture three-dimensional, stereo imagery, the satellite was also equipped with two cameras, one facing forward and another facing rear, or aft, such that the distortion found in these two cameras are opposite one another. These characteristics result in severe spatial distortions that radically alter the shape and size of individual features, as in the case of Zincirli Hoyuk in southern Turkey (Fig.11). This Iron Age fortified site possesses a nearly perfectly circular wall enclosing an area of around 40-hectares, but in uncorrected CORONA imagery it appears as an oblong oval, distorted in opposite directions on forward and aft cameras.

Figure 10: Original CORONA film strips like those pictured above contain extreme spatial distortions caused by the satellites' panoramic camera systems.

Figure 11: Uncorrected images from forward and aft CORONA cameras of the site of Zincirli Hoyuk in southern Turkey. Compare to the circular shape of the city wall as mapped in the 1890s.

Until recently, most researchers who attempted to correct the spatial distortions contained in CORONA imagery, a process termed “rectification,” have relied on fairly simple methods that are standard on many image-based GIS software packages, but which are not designed to deal with highly distorted and irregular images like CORONA. In general, researchers clip a small segment of the long panoramic image, and then the segment is stretched to match another map or satellite image by selecting a series of ground control points (GCPs) visible on both images. This process, termed “rubbersheeting,” represents a coarse, algebraic generalization of the imaging process and does not take into account the differential distorting effects caused by the terrain or the imaging geometry. Rubber-sheeting is also extremely time consuming because each small image segment must be individually rectified using a large number of GCPs and then stitched together to produce a larger map. Previous efforts by Casana (2003) and other researchers using these methods to rectify KH-4B CORONA imagery resulted in errors of 100m or more on flat terrain, with significantly larger errors in mountainous regions (Fig.2.4).

Thanks to previous support from NEH, we have now developed a means to efficiently correct spatial distortions across entire scenes using a method that accounts for distortions caused by both camera geometry and topography, a process termed "orthorectification." Our method, discussed below, has been used to correct more than 1200 images from across the Near East, making them available to view and download through our custom built website http://corona.cast.uark.edu/. We also provide tools enabling researchers to quickly locate archaeological sites of interest, to compare 1960s CORONA images with modern, Google-served imagery, to incorporate the imagery into their own research projects. In addition we provide tutorials for more advanced applications of the imagery including stereo analysis and digital elevation model extraction (Casana et al. 2012). While still in a Beta version, our CORONA website has received much attention and praise by archaeologists from around the world, with images taken from the website appearing in more than a dozen conference papers presented at the recent International Conference on Archaeology of the Ancient Near East (ICAANE) in Warsaw during April 2012.

CORONA as a Global Resource for Archaeology

Outside of the Near East, where the value of CORONA imagery is now well demonstrated, its potential to aid in archaeological research has been explored in a handful of other regions, including Central Asia (Gheyel et al. 2004; Goossens et al. 2006), southern England (Fowler 2002), eastern China (Min 2010), and the Upper Indus Valley (Wright and Hritz, in press). All these studies conclude, unsurprisingly, that CORONA imagery offers great possibilities for the same kinds of research that has been undertaken in the Near East. Yet such work remains in its infancy, in part due to the tremendous challenges involved in correcting spatial distortions found in CORONA images and in part because archaeologists working in those regions are unclear about how to integrate this resource into research programs. At the most recent meeting of the Society for American Archaeology in April 2012, we offered a half-day workshop teaching participants how to acquire CORONA, how to correct the spatial distortions found in the imagery, and how to deploy it in archaeological projects. The workshop was fully booked within days of its offering and was attended by many unregistered participants who stood in the back of the room. Following the workshop, we received dozens of requests from other researchers who could not attend, but who heard about the offering and wanted to have copies of workshop teaching materials. Virtually all the scholars we encountered were interested in pursuing CORONA-based archaeological research in regions outside the Near East, in part spurring us to apply for this grant.

This proposal seeks support to expand CORONA imagery coverage into parts of the world where we believe it will be extremely valuable to research in archaeology and other fields. Our previous research, supported by the NEH, successfully developed efficient methods for orthorectification of CORONA imagery over large areas, and as part of that project, we corrected over 1200 images from across the Near East. We now seek to deploy these techniques in other regions of the world where CORONA will very likely prove to be a similarly powerful resource. Specifically, we plan to focus work on central and eastern China, southeastern Europe (Bulgaria, Romania and surrounding regions), south Asia (particularly the Indus Valley and adjoining areas) central Asia (Turkmenistan, Azerbaijan, and northern Afghanistan) and the African Sahel (from Mali to Sudan). All of these regions possess archaeological sites and features that are resolvable on CORONA imagery insofar as they were home to ancient urban civilizations that left a prominent record of major settlements, agricultural installations and similar features. Many of the sites in these areas are located in agricultural plains and flat valleys where site visibility is likely to be good. Furthermore, all these areas were places of interest to Cold War-era US military satellite observation, meaning there are a relatively large number of CORONA missions available. Finally, all of these regions have seen high rates of development in recent decades, transforming the landscape and obscuring many ancient sites.

Our own pilot studies in coastal Bulgaria and central China were quite successful. For example, in the agricultural plain around the ancient Chinese capital of Xian, development since the 1960s has been intense (Fig. 12), but CORONA imagery reveals a largely pre-industrial landscape, including many archaeological features (Fig. 13).

Figure 12: An area north of Xian, China where many archaeological sites are visible on CORONA imagery from 1967 (left) have been destroyed by modern development (right).

Figure 13: A monumental tomb complex in the region of Xian, China; one of many archaeological sites and features in the region that have been impacted by development.

Our plan will be to correct approximately 3000 images over a three-year period, making these images and similar mapping resources available through a general CORONA Atlas website, modeled on the success of our existing platform. Our research team is uniquely situated to pursue this project, having now developed the methodologies for correcting and distributing CORONA imagery. While our methods, summarized briefly below, have now been published, they remain difficult to replicate for most researchers because they require data to be moved across numerous proprietary software platforms and also take advantage of several pieces of custom built software and code we developed for the project. In addition to correcting the imagery itself, we also plan to streamline our correction methodology, thereby providing all the tools necessary for other researchers to replicate our methods with relative ease. The techniques can then be applied to any panoramic CORONA image, as well as to other similar images that are only now being declassified, specifically the Hexagaon and Gambit satellites (McDonald and Widlake 2012).

HISTORY, SCOPE AND DURATION

The proposed project will be undertaken over a period of three years, from June 2013 to June 2016. Over this time period we plan to work steadily to correct approximately 3000 CORONA images covering all of the areas we outline. Images will be provided in stereo wherever possible to facilitate 3D analyses. The project builds substantially on work completed over the past several years as part of a previous project.

Project PIs Casana and Cothren received an initial grant from the NEH in August 2008 (CORONA Archaeological Atlas of the Middle East" (PW-50083-08), and we completed work in October 2011, with the launch of a fully-functional CORONA website of the Near East. Our first year of work on the project was also supported by a grant from the American Council of Learned Societies and the project benefited from the donation of imagery from numerous colleagues, notably the Oriental Institute of the University of Chicago. The completion of our initial project has received significant attention in the Near Eastern archaeological community and the website has a growing audience of users.

Our research team is now poised to bring CORONA imagery, a resource that has proven to be transformative in Near Eastern archaeology, to a much wider, global audience and to scholars working in diverse parts of the world. The project is planned to take three years to complete, with a minimum number of corrected images estimated at 3000 over that time period. Our previous experience working with these images ensures that this goal is achievable, that the platform for delivering imagery is robust, and that results will offer great potential to scholars across a variety of disciplines.

In addition to our CORONA Atlas website itself, numerous publications reporting on various aspects of our work to date have appeared. These include:

Casana, Jesse; Jackson Cothren and Tuna Kalayci. 2012. Swords into Ploughshares: A CORONA Satellite Imagery Atlas of the Near East. *Internet Archaeology.*

Casana, Jesse. 2012. Site Morphology and Settlement History in the Northern Levant. In, *Proceedings of the 7th International Conference on the Archaeology of the Ancient Near East, London, March 2010.* The British Museum & University College London Press, pp. 593-608.

Casana, Jesse and Jackson Cothren (In press) The CORONA Atlas Project: Orthorectification of CORONA Satellite Imagery and Regional-Scale Archaeological Exploration in the Near East. Douglas Comer and Michael Harrower (eds.) *Handbook of Space Archaeology.* NASA and ICOMOS.

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METHODOLOGY AND STANDARDS

Much of our work on the CORONA Atlas of the Middle East Project has been dedicated to developing new methods to correct the spatial distortions found within raw CORONA imagery. The unusual cross-path panoramic cameras employed on CORONA satellites maximized both the area that could be covered in a single frame and the resolution of the final image, but resulted in severe spatial distortion, as discussed above. Because most necessary information (camera parameters, satellite position and orientation, etc.) for automated orthorectification of CORONA is not available, we have essentially reverse engineered the image correction process. Our efforts have now developed a method for efficient, rigorous orthorectification of full CORONA scenes, a process that corrects image distortion based on a mathematical model of the camera and its relationship to the ground surface. Our methods, described in more detail in Cothren et al. (in press) and Casana et al. (2012), are outlined below.

Image Pre-Processing

The United States Geological Survey (USGS) who distribute CORONA imagery, has since 2004 provided CORONA images in digital format. Due to its large dimensions, CORONA film negatives are scanned in four parts, and the user obtains these files separately. Therefore, any study dealing with a large number of CORONA images has to develop strategies to automate the process of stitching the parts back into original sizes of CORONA image strips. We perform this automation with the help of scale-invariant feature transform (SIFT) algorithms, a computer vision algorithm which detects local features in a digital image (Lowe 2004) built over open source library functions (Vedaldi and Fulkerson 2008). The SIFT detector extracts a large number of robust frames from an image which can be directly compared to other frames from other images since these frame signatures are all illumination, scale, and viewpoint invariant. With this approach, it is possible to merge images by tying the frames together. By automating the SIFT process, we are able to reconstruct large numbers of CORONA images efficiently and with a high degree of accuracy. Once reconstructed, images are assembled into blocks containing from 10-50 images that are part of a single revolution of a satellite, and thus were taken within a few minutes of one another. Because original fiducial marks are not visible on many scanned

CORONA images, we also then generate a series of pseudofiducials that mark the corners of scanned images to better determine image size and shape.

Ground Control Point Collection

Unlike modern satellite images, CORONA images do not have high-quality position and orientation metadata available, and so these variables must be estimated using measured ground control points (GCPs)—points identifiable on both CORONA images and modern, orthorectified imagery. Because of the massive transformations in the landscape since CORONA missions were flown, finding features visible on both CORONA and modern imagery is challenging and time-consuming. We rely on Google Maps (maps.google.com) image data to locate horizontal ground control points. While many questions persist regarding the spatial accuracy of images served by Google, there is simply no other practical source for ground control across the enormous area we cover in the CORONA Atlas project. Furthermore, the subsequent bundle block adjustment step (see below) is a least-median of squares (LMedS) optimization which is robust in the presence of outliers. To facilitate the ground control point collection process, we developed a custom-built point digitizing tool using Google's Application Programming Interface (API). The tool enables us to quickly collect and store points from Google data while simultaneously locating the same points on CORONA images within ERDAS Leica Photogrammetry Suite (Fig.14). For each CORONA scene, we collect 15-20 GCPs, spread across the entire images, primarily in areas of overlap between successive images in a block (Fig.15). The elevation of these locations is then derived from an SRTM Level 1 digital elevation model, which provides reliable and sufficiently high resolution elevations for our process.

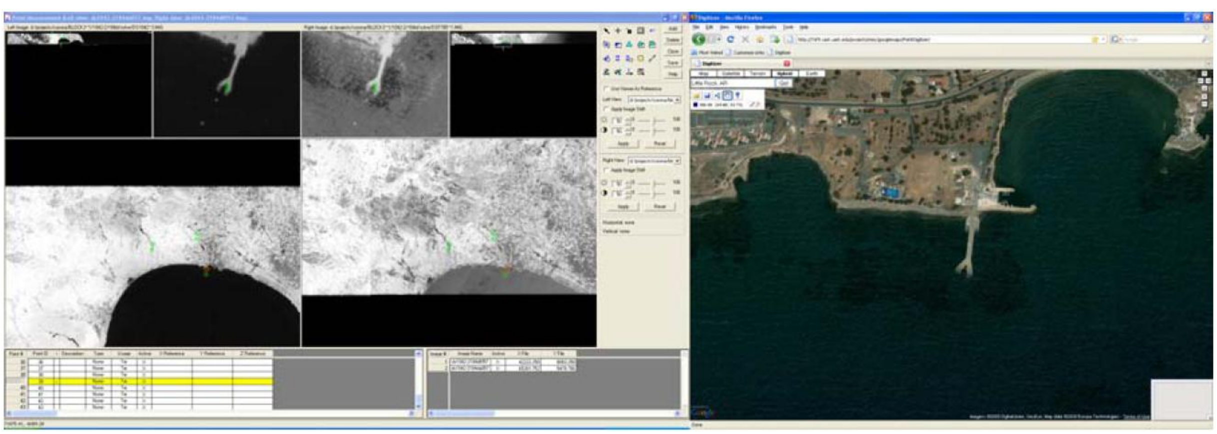

Figure 14: Ground control point collection using ERDAS Leica Photogrammetry Suite (left) and custom built point digitizing tool using Google's API (right).

Block Bundle Adjustment

The third step in the process is commonly termed bundle adjustment, in which the orientations of CORONA scenes are estimated simultaneously. Unlike modern satellite images, the orientation of CORONA images cannot be obtained via direct means and must be estimated indirectly using ground control points. Following a solution proposed by Sohn et al. (2004), a rigorous sensor model is created for each CORONA scene which contains camera parameters (i.e. focal length, scan rate, position, and orientation) and thus a mathematical description of distortions caused by the CORONA camera. Once panoramic sensor model equations are defined, the model parameters are estimated with the help of GCPs in an LMedS optimization. After these parameters are estimated, they can be used to map ground points (latitude, longitude, and height) to a particular pixel in the image (Fig.15). However, no commercial GIS is able to make direct use of these parameters and display the image correctly. We therefore follow a procedure used by high resolution satellite vendors to map a these unusable parameters to a well-known set of general parameters known as Rational Polynomial Coefficients, or RPC's. Since all commercial satellite vendors use the same set of RPC's, virtually all GIS software with basic image processing capabilities can project the RPC-enabled CORONA images to a ground plane or DEM. This process, called orthorectification, is the next step in the process.

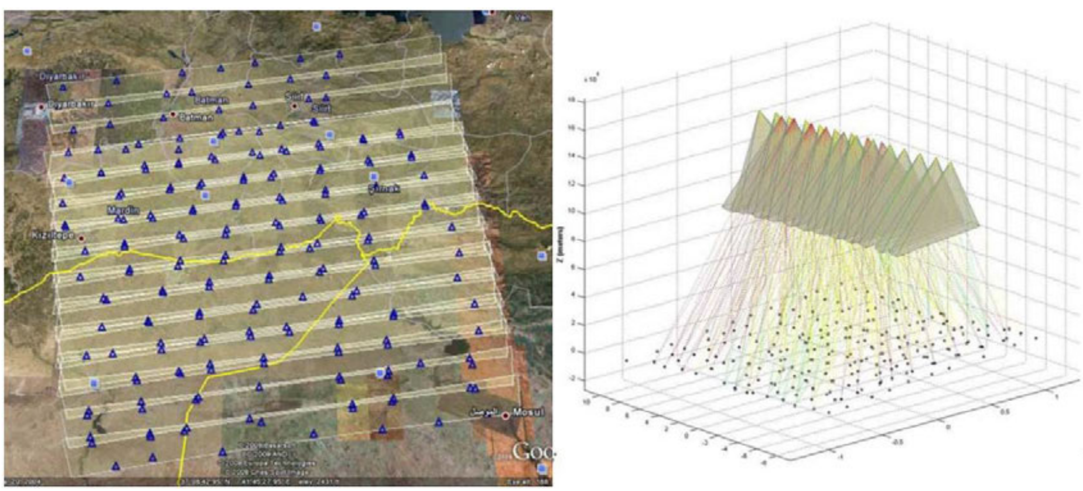

Figure 15: Collection of ground control points across a series of CORONA images (left); Our methods enable triangulation of images in space and accurate orthorectification (right).

Orthorectification

The final stage of our correction process corrects for errors due to topographic relief, a process termed orthorectification. Once an image is orthorectified, relief displacement of the terrain is removed, and geographical features appear in their true locations. We orthorectify CORONA images by projecting them over a digital elevation model, generally the SRTM Level 1 DEM with a nominal ground resolution of 90 meters. The digital elevation model is equally sampled for ground coordinates and for their elevation values, such that the accuracy of the base digital elevation model is of immense importance for the overall process. Studies show that while higher resolution DEMs may be available, the SRTM provides very high accuracy consistently across the region (Rodriguez et al. 2006). Our analysis shows that the accuracy of most of our orthorectified images range from 3-10 meters at nadir to 20-30 meters at the edges

(Cothren et al., in press; Fig.2.8). The low accuracy at the edges of terrain corrected images is due to the panoramic scan of the CORONA sensors, where the effects of unmodeled distortions in the rigorous sensor model are most apparent. Occasionally, individual images or an entire block of images (those derived from a single camera during the same satellite revolution) produce less than optimal results or fail completely. We are continuing to evaluate the reasons for such failures, but they are most likely the result of image distortions that are unknown to us, derived for example from how the images were scanned, stretching or deformation in the physical film strips, or similar issues.

SUSTAINABILITY OF PROJECT OUTCOMES AND DIGITAL CONTENT

CORONA images in the online Atlas are stored in National Imagery Transmission Format (NITF), an imagery standard developed by the US Department of Defense that allows us to embed the original image, RPCs and other data used to geometrically correct the imagery, along with other metadata in a form that is recognized by most GIS software. These NITF images then are orthorectified “on-the-fly,” being projected onto an SRTM digital elevation model as the user pans through the data, rather being served as static, orthoimages. We chose this on-the-fly method (implemented using ArcGIS Server Image 10.0) for several reasons. First, orthorectifying all 1200+ images in the Atlas is a time consuming process that, once completed, removes most opportunities for accuracy enhancement by the inclusion of better ground control points or higher accuracy DEMs. Second, because most CORONA orbits had significant inclinations, the scan direction is rotated by several degrees from north. The orthorectified image must be rectangular and the “dead-space” can cause the size of a single CORONA scene to increase from 1GB to as much as 4GB. While compression techniques can reduce the file size, image display and processing speed can suffer, while downloading images would become problematic for many users.

A user who wishes to download and display a fully orthorectified image in GIS software can download the approximately 1GB NITF CORONA image along with the underlying SRTM DEM. Following simple procedures outlined in the Help menu, users can then link the image and DEM in GIS software packages (ArcGIS 9.31. or higher, ERDAS Imagine, and ENVI to name a few) producing the same orthoimage viewed in the online Atlas. While this complicates the task of properly displaying a downloaded image, the flexibility it provides is worth the effort. Users who require higher accuracy can input a few high-quality ground control points or project the image onto a higher resolution DEM, either of which will improve the accuracy orthorectification. The NITF format also preserves the capability of CORONA images to be used for DEM extraction and other photogrammetric processes (see, “CORONA in 3D”). For users wishing to download only a small portion of the orthorectified CORONA scene, the Atlas provides a snapshot tool which saves the current view in orthorectified form as a PNG file. These small clipped images can then be easily incorporated into presentations, publications, or other uses with little effort.

All NITF images from the Middle East have been archived in the University of Arkansas’s ARKive system (http://dora.uark.edu/fedora/repository/islandora:2279). ARKive runs on virtual servers hosted on Dell server hardware running Redhat Enterprise Linux clusters with real-time failover to a disaster recovery site located at a separate and secure physical location. The clusters currently use Dell Compellent fiber channel storage mirrored asynchronously to the disaster recovery site. The virtual servers run the repository applications DSpace, and Fedora Commons, as well as Tomcat, Drupal, and Islandora as supporting applications to the primary repository services, Shibboleth authentication is available. All images processed as part of this proposed project will also be archived in ARKive.

DISSEMINATION

Results of our work will be presented a several international conferences each year, including the Society for American Archaeology and the Association of American Geographers annual meetings, thereby reaching a large audience of interested scholars from across several disciplines. We also plan to host an annual half-day-long training workshop at the SAA Annual Meeting, as we did for the first time at the meeting in Memphis in April 2012. There, we taught a full room of interested scholars, students and professional archaeologists the basic methods for image correction, site identification, and 3D analysis of CORONA imagery. The success of the program leads us to believe it will be a very good method for dissemination of project results in the future.

In addition to the main product of the project--geometrically corrected CORONA imagery for many parts of the world—we also plan to provide reports of project progress as well as archaeological analyses of imagery in numerous publications. General discussions of the project and its outcome will be submitted for publication in Antiquity, one of the leading journals for method and theory in archaeology that reaches a global audience, as well as in Archaeological Prospection, the top journal for technical studies of remote sensing in archaeology. Technical aspects of the project, including improved methods for efficient orthorectification of imagery, will be published in International Journal of Remote Sensing. Analyses of individual finds from different regions will be published in more targeted field-specific journals. In addition to traditional print publications, we also plan to submit a paper for electronic publication in Internet Archaeology, a forum that will enable more interaction with the imagery and its research potential.

Publications, talks and workshops will be supported by an array of training materials, tutorials and best-practice guides for application of CORONA imagery in research projects, all made freely available through the CAST GeoMetaVerse website: http://gmv.cast.uark.edu

Finally, we anticipate some popular and media coverage of our work. We have recently reached a tentative agreement with Google to have our registered CORONA imagery hosted for viewing on GoogleEarth through the application's time-slider, a tool enabling users to pan backwards in time to earlier satellite missions. When our CORONA appears on Google, many non-specialists will likely see the imagery there. We also plan several press released through our university press office to popular media outlets.

WORK PLAN

May 2013-August 2013:	Selection and acquisition of imagery from USGS and other sources; hiring and training of student staff members (Casana, Cothren)
August 2013-April 2014:	Processing of China imagery (Barnes, students)
April 2014-October 2014:	Processing of southeastern Europe imagery (Barnes, students)
October 2014-January 2015:	Processing of South Asian imagery (Barnes, students)
February 2015-July 2015:	Processing of Central Asian imagery (Barnes, students)
August 2016-January 2016:	Processing of African imagery (Barnes, students)
February 2016-June 2016:	Preparation of final reports; production of user-friendly orthorectification process (Casana, Cothren, Wilson)

STAFF

Jesse Casana, Associate Professor, Department of Anthropology, University of Arkansas Project director; oversees planning and implementation; selects image series to be included in the Atlas; trains and supervises staff members; leads publication and dissemination of project outcomes. Planned Time: 2 months/year.

Jackson Cothren, Director, Center for Advanced Spatial Technologies and Associate Professor, Department of Geosciences, University of Arkansas Project co-director; assists with planning and implementation; oversees CAST research associates; trains CAST staff members in image processing techniques; oversees construction and maintenance of online database. Planned Time: 1 month/year.

Adam Barnes, Research Associate, Center for Advanced Spatial Technologies, University of Arkansas. Oversees processing of imagery and ensures quality control of product images; supervises hourly student employees in collection of ground control points and other tasks. Planned Time: 6 months/year.

John Wilson, Research Associate, Center for Advanced Spatial Technologies, University of Arkansas. Oversees construction and maintenance of servers and data distribution website. Planned Time: 1 month/year.

Hourly student research assistants. Process imagery according to established protocols.

History of Grants:

SPONSOR:	National Endowment for the Humanities
TITLE:	CORONA Archaeological Atlas of the Middle East
AMOUNT:	$338,000
DATES:	August 2008-October 2011
DESCRIPTION:	This grant supported the creation of the CORONA satellite imagery-based archaeological atlas of the Middle East.

SPONSOR:	American Council of Learned Societies: Digital Innovations Fellowship
TITLE:	CORONA Archaeological Atlas of the Middle East
AMOUNT:	Salary replacement plus $25,000
DATES:	August 2008-May 2009
DESCRIPTION:	This fellowship provides salary replacement and $25,000 in research funds to support work on the CORONA imagery atlas project.

List of Participants:

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Cothren, Jackson, Director, Center for Advanced Spatial Technologies and Associate Professor, Department of Geosciences, University of Arkansas

Wilson, John, Research Associate, Center for Advanced Spatial Technologies, University of Arkansas

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Yener, K.A., Edens, C., Harrison, T., Verstraete, J. and Wilkinson, T.J. 2000 'The Amuq Regional Archaeological Survey' *American Journal of Archaeology* **104** (2). 163–220.

Jesse Casana
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http://www.uark.edu/depts/anthinfo/casana.htm

(a) Professional Preparation

University of Texas at Austin	Archaeological Studies	B.A. 1996
University of Chicago	Near Eastern Archaeology	M.A. 2000
University of Chicago	Near Eastern Archaeology	Ph.D. 2003

(b) Appointments
Associate Professor, Department of Anthropology, University of Arkansas (2010-present)
Assistant Professor, Department of Anthropology, University of Arkansas (2004-2010)

(c) Publications

<u>*Five Pertinent Publications:*</u>

Casana, Jesse; Jason T. Herrmann. 2010. "Settlement History and Urban Planning at Zincirli Höyük, southern Turkey." *Journal of Mediterranean Archaeology* 23 (1): 55-80.

Casana, Jesse, Hussein Qandil and Jason T. Herrmann. 2009. "Settlement history in the eastern Rub al-Khali: Preliminary report of the Dubai Desert Survey (2006-2007)," *Arabian Archaeology and Epigraphy* 20: 30-45.

Casana, Jesse, Jason T. Herrmann and Aaron Fogel. 2008. "Deep subsurface geophysical prospection at Tell Qarqur, western Syria," *Archaeological Prospection* 15: 1-19.

Casana, Jesse, and Jackson Cothren. 2008. "Stereo analysis, DEM extraction and orthorectification of CORONA satellite imagery: Archaeological applications from the Near East," *Antiquity* 82: 732-49.

Casana, Jesse. 2007. "Structural transformations in settlement systems of the northern Levant," *American Journal of Archaeology* 111 (2): 195-221.

<u>*Five Other Publications:*</u>

Casana, Jesse. In press. "Settlement, Territory and the Political Landscape of Late Bronze Age Polities in the Northern Levant," In Parker VanValkenburgh and James Osborne (eds.), *Home Turf: Archaeology, Territoriality, and Politics*. Archaeological Papers of the American Anthropological Association.

Casana, Jesse. 2009. "Alalakh and the archaeological landscape of Mukish: The political geography and population of a Late Bronze Age kingdom," *Bulletin of the American Schools of Oriental Research* 353: 7-37.

Casana, Jesse. 2009. "The Breakfast Cereal Survey: Teaching archaeology with twelve essential vitamins and minerals," *SAA Archaeological Record.* (September 2009)

Casana, Jesse. 2008. "Mediterranean Valleys revisited: Linking soil erosion, land use and climate variability in the northern Levant," *Geomorphology* 101 (3): 429-42.

Casana, J; Wilkinson, T.J. 2005. "Settlement and landscapes in the Amuq region," In K.A.Yener (ed.), *The Amuq Valley Regional Projects, Volume 1, Surveys in the Plain of Antioch and Orontes Delta, Turkey, 1995-2002.* (Oriental Institute Publication No. 131). Chicago: Oriental Institute Press, pp. 25-65..

(d) Synergistic Activities

<u>Director, Institute for Digital Archaeology:</u> This NEH-funded program offers pre- and post-doctoral archaeologists the opportunity to spend a semester in residence at the University of Arkansas' Center for Advanced Spatial Technologies. Visiting fellows take courses in geospatial technologies, pursue independent research using CAST facilities, and participate in CAST-supported field projects.

CORONA Archaeological Atlas Project: Much of my research involves the use of declassified Cold War-era CORONA satellite photography. I have recently completed production of a digital, CORONA-based archaeological atlas of the Middle East. The resource offers remarkable research opportunities in the region.

Settlement Systems and Environmental Change in the northern Fertile Crescent: This 3-year NASA-funded Space Archaeology project seeks to exploit the availability of CORONA satellite imagery produced by our team. We are seeking to document all visible archaeological sites and features across the northern Fertile Cresent and to examine their distribution vis-à-vis environmental variables.

Dubai Desert Survey (United Arab Emirates): In cooperation with the Dubai Department of Archaeology, I am currently directing a regional archaeological survey project in desert regions of Dubai (UAE). The project integrates geomorphological and archaeological studies in the same way as the proposed project, and also utilizes a variety of geophysical prospection techniques.

(e) Collaborators and Other Affiliations

Collaborators and Co-Editors

Jackson Cothren, University of Arkansas
Jason Tullis, University of Arkansas
Amy Rebecca Gansell, Harvard University
Jason Ur, Harvard University
Tony J. Wilkinson, Durham University, England
Rudolph Dornemann, ASOR
Sarah Graff, University of Chicago
Jennifer Smith, Washington University in St. Louis
Alexia Smtih, University of Connecticut
Jason Herrmann, University of Arkansas
Aaron Fogel, University of Arkansas
Hussein Qandil, Dubai Department of Archaeology

Graduate Advisors

Tony J. Wilkinson, Durham University, England
Nicholas Kouchoukos, University of Chicago
K. Aslihan Yener, University of Chicago

Thesis Advisor

Tony J. Wilkinson, Durham University, England

Jackson Cothren, Ph.D.

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Professional Preparation

Ph.D. Geodetic Science and Surveying, The Ohio State University, 2004

M.S. Geodetic Science and Surveying, The Ohio State University, 2001

B.S. with Honors, Mathematics, United States Air Force Academy, 1989

Positions

Director, Center for Advanced Spatial Technologies, University of Arkansas. July 2009 – Present

Associate Professor, Department of Geosciences, University of Arkansas. July 2010 – Present

Assistant Professor, Department of Geosciences, University of Arkansas. July 2004 – June 2010

Research Assistant, Center for Advanced Spatial Technologies, University of Arkansas. November 2002 – July 2004.

Photogrammetric Engineer, National Air Intelligence Center, US Air Force. December 1999 – June 2001.

Officer/Scientific Analyst, National Air Intelligence Center, US Air Force. August 1990 – December 1998.

Relevant Publications

Cothren, J. and B. Schaffrin, *Comparison of Error Propagation in Block Orientation: An Analytical Approach*, Archives of the International Society of Photogrammetry and Remote Sensing, ISSN 1682-1777, 2010, Vol. 38, No. 7A, pp. 25–30.

Warn S., W. Emeneker, J. Gauch, J. Cothren, A. Apon, *Accelerating Image Feature Comparisons using CUDA on Commodity Hardware*, Symposium on Application Accelerators in High Performance Computing (SAAHGPC'10), 2010. `http://saahpc.ncsa.illinois.edu/10/papers/paper_15.pdf`

Warn, S. W. Emeneker, J. Cothren, A. Apon, emphAcceleration SIFT on parallel architectures, IEEE International Conference on Cluster Computing and Workshops, 2009. CLUSTER '09. ISSN: 1552–5244, Print ISBN: 978–1–4244–5011 doi: 10.1109/CLUSTR.2009.5289155

Casana, J. and J. Cothren. *Stereo analysis, DEM extraction, and orthorectification of CORONA satellite imagery: Archaeological applications from the Near East*, Antiquity, 2010, Volume 82, Number 217, pp. 732-749.

Schaffrin, B., and J. Cothren. *Hierarchical data fusion with photogrammetric applications*, Brazilian Journal of Cartography, 2004, No. 55/02, pp. 25-34.

Other Publications

Cothren, J. *Reliability in Constrained Gauss-Markov Models: An Analytical and Differential Approach with Applications in Photogrammetry*. Report #473, 2005, Geodetic and GeoInformation Science, Ohio State University, 61 pages.

Tullis, J., J. Cothren, D. Irwin, C. Yeager, W.F. Limp, J. Wilson, B. Gorham, S. Ogle. *Yearly Extraction of Central Americas Land Cover for Carbon Flux Monitoring*. GIScience and Remote Sensing, Vol. 44, No. 4. (December 2007), pp. 334-355.

Schaffrin, B. and J. Cothren, *Towards optimizing hierarchical data revisions*, Proceedings of the 9th Symposium on GIS: Between Vision and Applications, Stuttgart, Germany, 1998, pp. 515-521.

Reddy, V., K. Neumeier, J. McFarlane, J. Cothren, C. Thompson, *Extending a Natural Language Interface with Geospatial Queries*, IEEE Internet Computing, vol. 11, no. 6, pp. 82-85, Nov./Dec. 2007, doi:10.1109/MIC.2007.124

Cothren, J., B. Smith, K. Damphousse, P. Roberts, *Geospatial and Temporal Patterns of Preparatory Conduct Among American Terrorists*, International Journal of Comparative and Applied Criminal Justice, 2007, Volume 32, Issue 1, pp. 23-41.

Synergistic Activities

Selected as Fulbright Specialist for geomatics applications in heritgate documentation and archaeology.

Appointed to the Arkansas State GIS Board representing Higher Education. The board oversees and advises the Arkansas Geographic Information Office which is responsible for developing the spatial data infrastructure for Arkansas.

Served as National Director representing the Central Region for the American Society of Photogrammetry and Remote Sensing

Collabators and Other Affiliations

Amy Apon, University of Arkansas; Nilanjan Banerjee, University of Arkansas; Sreekala Bajwa, University of Arkansas; Jesse Casana, University of Arkansas; Brady Cox, University of Arkansas; Kelly Damphousse, University of Oklahoma; Maruo Diluzio, Blackland Research and Extension Center, Texas A&M University; Robert Dzur, Bohanan Huston, Inc; Michael Hargrave, U.S. Army Corps of Engineers, Civil Engineering Research Laboratory; Ayman Habib, University of Calgary; Larry Handley, United States Geologic Survey; Pamela Jansma, University of Texas, Fort Worth; William Johnston, University of Arkansas; Fred Limp, University of Arkansas; Glen Mattioli, University of Arkansas; Pat Parkinson, University of Arkansas; Michael Plavcan, University of Arkansas; Burkhard Schaffrin, Ohio State University; Toni Schenk, Ohio State University; Brent Smith, University of Arkansas University; Douglas Spearot, University of Arkansas; Robert Sullivan, Argonne National Laboratory; Greg Thoma, University of Arkansas; Craig Thompson, University of Arkansas; Jason Tullis, University of Arkansas; john Veil, Argonne National Laboratory; Joseph Wartman, Drexel University

Recent research students with whom I have coauthored publications: Kwasi Asanti; Hung Bui; Wesley Emeneker; Seth Warn; Mansour de Leh; Hayley Hames

Graduate and Post-Doctoral Advisors: Prof. Burkhard Schaffrin, The Ohio State University; Prof. Ayman Habib, University of Calgary

Doctoral Thesis Advisor: Prof. Burkhard Schaffrin, The Ohio State University

Adam R. Barnes

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Professional Experience

Center for Advanced Spatial Technologies, University of Arkansas

Geomatics Specialist, Multiple research projects that included components of GIS based analysis and model development; terrestrial, aerial, and orbital remote sensing and photogrammetry; object based image segmentation and classification; and spatial data management. Aug 2006 – Present

Graduate Research Assistant, Research project with goal of mapping and prioritizing Arkansas wetlands for restoration and preservation utilizing multiple GIS and remote sensing tools to manipulate and analyze various spatial data. Jan 2005 – Aug 2006

Oklahoma Center for Rural Development, Tahlequah, OK

GIS Internship, Conducted GIS analysis and cartography used for the creation of multivariate thematic maps for an online atlas of Oklahoma by obtaining and converting census data into ArcView 3.3 compatible database files. Jan 2004 – Jul 2004

Education

M.A. Geography, University of Arkansas Aug 2006

Thesis: “A Repeat Survey of Bathymetry, Sedimentation, and Aquatic Vegetation of Lake Wedington, Washington County, Arkansas”

B.A. Geography and Business, Northeastern State University May 2004

Current Publications/Presentations

Barnes, A., J. Cothren, K. Niven (2011). Guides to Good Practice: Close-Range Photogrammetry. Archaeology Data Service / Digital Antiquity: Guides to Good Practice. http://guides.archaeologydataservice.ac.uk/g2gp/Photogram_Toc

Barnes, A., J. Wilson (2011). ArcMap Tool for Comparing Digital Elevation Models (DEM) with Differing Resolutions. Arkansas GIS Users Forum Symposium, Bentonville, Arkansas, August 31-September 2, 2011.

Cox, B.R., J. Cothren, A. Barnes, J. Wartman, J. Meneses, A. Rodriquez-Marek (2010). Towards Quantifying Movement of a Massive Lateral Spread using High-resolution Satellite Image Processing. Opportunities for Emerging Geospatial Technologies: The ASPRS 2010 Annual Conference, San Diego, California, April 26-30 2010. [refereed]

Limp, W.F., A. Payne, S. Winters, A. Barnes and J. Cothren (2010). Approaching 3D Digital Heritage Data from a Multi-technology, Lifecycle Perspective. Proceedings of the 38th Annual International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA), Granada, Spain, April 6-9, 2010. (Submitted for publication in refereed proceedings)

Vranich, A., A. Barnes, J. Cothren and W. Limp (2010). Recreating Cuzco in Three Dimensions. Program and Abstracts for the 38th Annual International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA), Granada, Spain, April 6-9, 2010.

Cothren, J., A. Barnes, J. Casana, and T. Kalayci (2009). Effects of Ground Control Point Accuracy on Triangulation and Ortho-rectification of Large Blocks of CORONA Images. Program and Abstracts for the 37th Annual International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA) "Making History Interactive", Williamsburg, Virginia, USA, March 22-26, 2009. Page 50.

Kalayci, T., J. Cothren, J. Casana, and A. Barnes (2009). Accuracy of DEM Generation from CORONA Stereo Pair Images. Program and Abstracts for the 37th Annual International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA) "Making History Interactive", Williamsburg, Virginia, USA, March 22-26, 2009. Page 51.

Cothren, J., D. Frederick, W.F. Limp, T. deNoble, A. Barnes, C. Goodmaster, C. Stevens (2008). Visualizing the Roman City: Viewing the past through multidisciplinary eyes. Proceedings of the 36th Annual International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA) "On the Road to Reconstructing the Past", Budapest, Hungary, April 2-6, 2008. (Submitted for publication in refereed proceedings)

Cothren, J. C. Goodmaster, A. Barnes, E. Ernenwein, A. Vranich, W.F. Limp, A. Payne (2008). Fusion of 3-dimensional data at Tiwanaku: An approach to spatial data integration. Proceedings of the 36th Annual International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA) "On the Road to Reconstructing the Past", Budapest, Hungary, April 2-6, 2008. (Submitted for publication in refereed proceedings)

Cothren, J., W. F. Limp, A. Payne, J. Herrmann, and A. Barnes (2006). Integrating Terrestrial LIDAR Point Clouds and Independent Close-range Images, Proceedings of the American Society of Photogrammetry and Remote Sensing National Conference, Reno, Nevada.

NAME: John M. Wilson, M.S.
TITLE: GIS Specialist
FIRM ASSOCIATIONS: Center for Advanced Spatial Technologies, University of Arkansas
YEARS EXPERIENCE: 17
EDUCATION: BS/1997/Geography/University of Arkansas/Fayetteville
MS/2003/Geography/University of Arkansas/Fayetteville

CURRENT EXPERIENCE AND QUALIFICATIONS:

Projects:

Corona Atlas: Designed, built, and managed 3 servers for imagery deployment and distribution. Developed an interactive website allowing users to display Corona imagery over a backdrop of Google Maps and download processed Corona imagery files.

Childhood Obesity: Project design, source data assessment, inter-agency coordination, data manipulation, development of methodologies, data analysis, and automation of data generation in coordination with UA Ag Economics and Agribusiness and the Arkansas Center for Health Improvement.

Terrorism and Extremist Violence in the US: Assisted in data acquisition, loading, and mining, troubleshooting and database design. Created an interactive website allowing users to browse and select data for download to perform further analysis.

Dairy Life Cycle Analysis: Gathered and processed data related to nitrogen and phosphorous impact of dairy operations in the US. Developed methods for analysis/comparison of dairy impact at a watershed level.

Arkansas Automated Reporting and Mapping System: Gathered and processed data to be included in the initial output. Developed automated process to create map and merge with an associated report. Web page design and creation, report design and creation, and project publicity.

Arkansas Breeding Bird Atlas: Developed methods for automating map and report production for online and print-quality publication of project data. Data collected for 205 species of breeding birds in Arkansas.

Air Force Mapping Project: In cooperation with UA Industrial Engineering, developed methodologies for illustrating parts delivery vectors for US Air Force bases and parts suppliers.

Washington/Benton County 2006 Aerial Imagery: Developed methodologies for processing the 2006 Pictometry imagery for two counties. Developed scripts and managed the processing of the data.

GeoStor: Supervised and coordinated the continuing effort to populate and maintain the first seamless digital database of Arkansas GIS data. Involved in data translation and conversion, data generation, data acquisition, script generation (Avenue and AML), data management, metadata development, database administration, software evaluation and troubleshooting, application design, presentation design, and cartographic design. Developed skills in Oracle 10g database admin and management, ArcSDE administration, ArcIMS application development, and FME workspace creation and management.

MesoStor: Coordinated the data loading effort for the Central American implementation of MesoStor, as part of a USAID/NASA project. Provided on-site training for MesoStor staff. Contributed to planning activities for the project, software application building, application testing and troubleshooting.

Fort Smith National Map Pilot: Co-Principle Investigator, involved in data processing, building web applications, software testing /analysis, and coordination with cooperators that include City of Fort Smith, U.S. Geological Survey, and Arkansas Geographic Information Office.

Arkansas National Map: Worked with researchers at the USGS to assist in the creation of the Arkansas National Map and integration of Arkansas' GIS data with surrounding states. The project was a cooperative effort with the USGS, State of Missouri, State of Kansas, and State of Arkansas.

AR-GAP Server: Coordinated the building of prototype web mapping/analysis site for Arkansas GAP data. Demonstrated advanced spatial capabilities and Oracle spatial to the USGS, among others.

Source Water Assessment and Protection: Involved in methodology development, data acquisition, data translation and conversion, data generation, data management (including maintenance, quality control, and storage), script generation, cartographic design, and report generation.

LULC Maps: Supervised and coordinated the production and distribution of LULC maps to each Arkansas Legislator, Coop Extension Agent, County Judge, Soil & Water Commissioner, and the Governor.

California Old Growth Forest Project: Assisted UAF Dendroclimatology Lab in developing methodologies for quantifying areas of old-growth Blue Oak forest in the state of California.

Texas Ancient Cross-Timbers Project: Assisted UAF Dendroclimatology Lab in developing methodologies for quantifying areas of old-growth Post Oak forest in the state of Texas.

Primate Dental Topography: Assisted Dr. Peter Ungar and his students with developing methods for analyzing dental topography of primates using ArcView.

Red Oak Borer Beetle Project: Developed remote sensing-based methodologies for identifying negative vegetation change in the Ozark National Forest and surrounding areas. Assisted UAF Entomology department in developing methodologies for analysis of red oak borer beetle infestation.

Community Asset and Development Information System 2000: Developed data for the CADIS Population Growth Model, including predicted locations of population growth.

Arkansas Wetlands Project: Assisted with development of methodologies used in the GIS analysis of Arkansas wetlands in the Gulf Coastal Plain, Mississippi Delta, and Ouachita Mountains.

Other Duties:

University Course Instruction: Developed the curriculum for and taught Vector Geographic Information Systems (ANTH/GEOG 4563) as a 3-credit-hour semester-long course at the U of A for 6 semesters.

Professional Short Course Instruction: ESRI Certified Instructor for ArcGIS 9.x, and have taught approximately 410 students in 35 professional short courses and seminars.

Software Support: Provides technical support for users of GeoMedia, GRASS, MicroStation, ArcView 3.x, Trimble Pathfinder Office, ArcGIS, eCognition, IDRISI, and PCI Geomatica.

Systems Administration: Manages more than 25 servers and more than 100 workstations.

Publications:

2007 Tullis, J.A., Wilson, J.M. et al. *Yearly Extraction of Central America's Land Cover for Carbon Flux Monitoring*. GIScience & Remote Sensing, Vol 4, No 4, pp 334-355

2006 Wilson, John. Product Review. *"Master Raster" with the Geographic Transformer*. Earth Imaging Journal, Vol 3 No 6

2006 Jason D Luscier, William L Thompson, John M Wilson, Bruce E Gorham, and Lucian D Dragut. *Using digital photographs and object-based image analysis to estimate percent ground cover in vegetation plots*. Frontiers in Ecology and the Environment, Vol 4 No 8, pp. 408-413.

2005 Wilson, John. Product Review. *FME Suite 2004 ICE*. GeoWorld, February 2005.

2004 Wilson, John & Brian Culpepper, Feature Length Review. *ArcGIS 9.0 A User's Guide to Changes and Added Functionality*. GeoWorld 17(8) pp. 38-41.

2003 Wilson, John. Product Review. *Migration Assistant for ArcView*. GeoWorld 16(4):51

2002 P. Ungar, J. Dennis, F. Kirera, J. Wilson, F. Grine. *Quantification of tooth crown shape by dental topographic analysis*. Poster presentation at the American Association of Physical Anthropologists Annual Meeting. April 10-14.

2001 Wilson, John. Product Review. *Pliable GIS for ArcView 8.1*. GeoWorld 14(11):64

2000 Wilson, J.M., L.J. Fye, R.B. Culpepper and W.F. Limp. *Spatial Data Development Methods for the Arkansas Source Water Assessment and Protection Project: An Assessment of Relative Contamination Risk to Each Public Water System in Arkansas*. Water Resources Issues in the Arkansas Delta: Proceedings of the Arkansas Water Resources Center Annual Conference (April 1999). Arkansas Water Resources Center Publication No. MSC 0, University of Arkansas, Fulbright College of Arts and Sciences.

2000 Wilson, John. Product Review. *theEngine 2*. GeoWorld 13(10):68