Space Archaeology
Abstracts of selected proposals.
(NNH09ZDA001N-SAP)

The National Aeronautics and Space Administration (NASA) solicited proposals that would utilize remote sensing data to improve our understanding of past human settlement patterns and the relationships between the natural environment and cultural adaptations as functions of time and space. This program uses space-age technology to understand an age-old problem, environmental change and how societies have generated and/or responded to that change with various degrees of adaptive success. The major goals of the Space Archaeology program are: (1) to accelerate archaeological discovery and understanding through access to and analysis of remotely-sensed data obtained from space borne and airborne platforms and (2) to facilitate the infusion of technological expertise and capacity in remote sensing into archaeological research by fostering multidisciplinary collaborative partnerships.

This solicitation requested proposals that use remotely sensed data in three focus areas:

• Identification and exploration of the extent and nature of past human settlement patterns,

• Regional landscape analysis and modeling that relate human settlement patterns and subsistence strategies to environmental factors derived from remote sensing (i.e., climate, topography, hydrology, vegetation cover, etc.), and

• Protection and preservation of cultural heritage sites and/or planning for sustainable development of cultural resources.

Proposals must incorporate use of remotely sensed data and/or derived products from NASA and/or data from other international space agencies with missions providing data types not available from NASA. This solicitation is not intended to support acquisition of commercial airborne or spaceborne imagery, nor is it intended to support extensive fieldwork such as excavation.

NASA received a total of 12 proposals, and 6 have been selected for funding. The total funding to be provided for these investigations is approximately $2 million over three years.

Joseph Carter/University of Texas at Austin
Remote Sensing for the Study of Ancient and Current Land Use at Metaponto in Southern Italy

We propose to use remote sensing to 1) investigate a system of property divisions that were part of fifth century BC land reforms in the agricultural territory of Metaponto, a Greek colony in southern Italy, and 2) compare the evidence of ancient land management
with modern reclamation practices. The central focus will be on human-environment interactions in this highly dynamic landscape.

Existing maps of the Greek land divisions will be improved using multi-spectral Quickbird and Landsat data and multi- and hyper-spectral ALI and Hyperion data. It is anticipated that subtle variations in spectral response from differential vegetation cover and/or soil composition will allow for better identification of the buried features than has yet been achieved by visual interpretation of aerial photographs. A DEM will be created from historic CORONA and/or aerial stereo photography to serve as a proxy for ancient topography. With the resulting datasets, we seek to determine whether the land divisions were connected with drainage and irrigation -- still problematic issues today.

For the study of modern land use, a DEM reflecting current topography will be extracted from ALOS PRISM data. It will be compared with the historic DEM to quantify major land remodeling since the 1950s. A series of land use maps from the 1940s to the present will be created from aerial and CORONA satellite photography and Landsat imagery.

These results will be used to compare ancient Greek land management with that of the last several decades. Ancient and modern human impacts on the natural environment (soil erosion, drainage problems, and coastal aggradation) will be assessed as will impacts from recent land modifications on the preservation of the archaeological record.

The project will contribute to the study of ancient Greek agriculture as well as to a broader understanding of how humans have impacted this and similar landscapes. It will also contribute to discussion of sustainable cultural and environmental management strategies locally and in the broader Mediterranean basin. The work is pertinent to all three focus areas of the NASA Space Archaeology Program and to the Earth Science Research Program focus area of Climate Variability and Change.

**Jesse Casana/University of Arkansas**

**Settlement Systems and Environmental Change in the Northern Fertile Crescent**

Focusing on the northern Fertile Crescent, a region extending from the eastern Mediterranean to northern Iraq, the proposed project will conduct a macro-level analysis of ancient settlement systems and the dynamic environments in which they existed. By coupling the power of declassified CORONA satellite imagery to reveal archaeological features with detailed environmental data available through NASA satellite programs, this project will map archaeological sites and landscape change over more than 200,000 sq km.

CORONA imagery dating to the 1960s-1970s has proven to be a uniquely valuable resource in identifying archaeological sites and cultural landscape features in the Middle East. Yet because it contains extreme, irregular distortions it cannot be readily imported into a GIS framework for analysis. Thus, while excellent CORONA coverage exists for the entire Middle East, it has only been used in a piecemeal way on a handful of relatively small-scale archaeological projects. The principle investigators of this proposal
are currently assembling a massive new database of orthorectified CORONA imagery of the Middle East and these data will enable us to utilize this unique resource in a far more systematic and robust way than has previously been possible. After establishing the morphological and reflectance characteristics of 1000-1500 archaeological sites, known from published archaeological surveys in the region, we will apply object-based segmentation to the orthorectified CORONA imagery using shape, gray-scale and topographic constraints to identify candidate sites. These candidates will then be evaluated by trained observers to determine whether the features are of archaeological significance, and if so, whether they can be classified into one of several distinct and datable site types.

The project will then attempt to model dynamic trends in land cover and environmental change, or land surface phenology, using Advanced Very High Resolution Radiometer (AVHRR) and Landsat data. We will rely on a 25-year (1981-2006) normalized difference vegetation index (NDVI) dataset derived from daily AVHRR data. These data will enable us to observe the changing extent and health of vegetation across the study area in order to establish both average and extreme conditions. Much higher resolution NDVI images derived from Landsat data during anomalous and average years or seasons will then be analyzed in order to better interpret trends visible in low-resolution (1km) AVHRR data. Results will be evaluated against contemporary gridded climate data, thereby illustrating the actual effects that years or seasons with higher or lower than average rainfall had on land cover throughout the study region.

In the northern Fertile Crescent, nearly all pre-industrial agriculture was dependent on highly variable and relatively sparse precipitation. Documenting the full effects that minor variations in climate can have is therefore critical to understanding settlement and land use history. Our methods will reveal the extent of settlement in the region and the effects that rainfall variability can have on the sustainability of agricultural systems. A detailed knowledge of how modern climate variability affects the landscape will provide a benchmark for assessing how past climate changes, as revealed through a variety of paleo-environmental and modeling studies, might have impacted ancient settlement. Results will thus enable us to determine if there are certain thresholds outside of which agricultural settlement was not possible, or alternatively, if some periods saw extensive settlement beyond the limits of what might be expected based on recent climate data. Thus, the proposed project supports NASA’s research objectives to better quantify long-term, global land cover change and to better understand the complex interaction of human activities and climate variability through time.

Stephen Leisz/Colorado State University
Remote Sensing in Support of Legacies of Resilience: The Lake Patzcuaro Basin Archaeological Project

Funding is requested for the acquisition and analysis of ALOS PRISM and AVNIR-2 data as part of a long-term project to understand the linked development of complex societies, climatic fluctuation, and human constructed landscapes over millennial time-frames within the Lake Pátzcuaro Basin (LPB), Michoacán, México. More specifically
these data will be integrated with on-going archaeological and paleoenvironmental investigations to examine propositions related to climatic fluctuation, landscape development, land degradation, and the formation of complex societies in the west central highlands of México. Our ultimate goal is to create and test models of linked human/environmental development and collapse over long time scales to inform modern and future conservation efforts throughout Latin America. A key aspect of the overall long-term Legacies of Resilience: The Lake Pátzcuaro Basin Archaeological Project project is to create explanatory models that predict the pre-Hispanic extent of the Tarascan State agricultural land within the LPB. In order to do this the accurate mapping of the changing lake level, and consequently changing lake extents, over time is needed. Currently available elevation data is not adequate for completing this task. This project will fill that need by using ALOS PRISM data to develop a high resolution digital elevation model (DEM) for the study site. This DEM will be used to underpin four predictive spatial models. The DEM, in conjunction with field observations and archaeological findings from previous field work, will be input into three conceptual models that have been developed to predict changes in pre-Hispanic lake shore extent; pre-Hispanic terrace locations, and pre-Hispanic raised agricultural field locations in the basin. The conceptual models have been developed from field observations, but never spatially extended and they have never been tested due to lack of appropriate data. A fourth model showing the maximum potential LPB agricultural area will be developed based on the outputs from these three models. The AVNIR-2 data will be pan-sharpened and used to create a high-resolution object oriented classification of the modern landscape with the specific aim of identifying visible terrace and raised field remnants. The visible terrace and raised field remnant classification in conjunction with ground truthing in the basin will be used to validate the model’s results. The ultimate output of this project will be the predictive modeling of the maximum potential agricultural area within the LPB. The results obtained from this project will allow for the spatial extension of results and knowledge obtained from the site specific archaeological work being done in the LPB to the whole basin. The project also addresses all three of NASA's Space Archaeology program focus areas and specifically furthers efforts to carry out regional landscape analysis and modeling that relate human settlement and land use patterns and strategies to environmental factors that can be derived from remote sensing data.

Michael Palace/University of New Hampshire
Analysis and Detection of Amazonian Black Earth Sites using Hyperspectral Satellite Imagery

The pre-Columbian indigenous population estimates of the Amazon Basin lowlands are highly uncertain, widely varying, and the subject of considerable controversy, partially due to the scarcity of data regarding the pre-European societies of Amazonia. Proponents of the low population density suggest that the forest is pristine, delicate, and sensitive to human disturbance. If populations were high, it is likely that Amazonian forest vegetation had been significantly altered and may be thought of as a cultural artifact, resilient to human disturbance and not an undisturbed forest. One of the archaeological sources used in reconstruction of Amazonian societies are Amazonian black earths (ABE) or in Portuguese, terra preta soils. The immense size of Amazonia, remoteness of many areas,
forest vegetation, and lack of archaeological field surveys, make remote sensing beneficial to archaeological studies in this region. Remote sensing allows for comparison and analysis of vegetation across vast areas. Previous research has shown that hyperspectral image data can detect vegetation canopy chemistry differences, associated with soil nutrients and chemistry. This literature suggests that the high nutrient content of ABE soils will cause detectable changes in vegetation structure, phenology, and/or foliar chemistry. Hyperspectral remote sensing with dense coverage of the spectral reflectance of vegetation canopies will provide a key to detection of high nutrient ABE sites. The broad spatial coverage afforded by the proposed research allows for the unique opportunity to begin to quantify the Pre-Columbian human impact in Amazonia through the analysis of the distribution of ABE sites across the region. Understanding these aspects of ABE sites provides information useful for both archaeological research and has consequences for the interpretation of ecology of Amazonian forests. Knowledge of the disturbance history of the Amazonian forest provides a context and framework for the placement of all recent and future scientific environmental research in the region.

Stephen Savage/Arizona State University
Climate Change and Human Impact on Ancient and Modern Settlements: Identification and Condition Assessment of Archaeological Sites in the Northern Levant from Landsat, ASTER and CORONA Imagery

This proposal seeks to address two questions related to urban development and collapse through the use of remotely sensed archaeological site data. 1) Was the urban collapse at the end of the Early Bronze Age (EBA ca. 3600-2000 BCE) in the Levant caused by climatic change? 2) How has recent development impacted the condition of archaeological sites in regions made inaccessible through conflict? Archaeological research in the southern Levant (Israel, the West Bank and Jordan) has revealed several cycles of settlement aggregation and dissolution starting in the EBA. It is unclear how or if these changes are equally manifested in the northern Levant (roughly Lebanon and Syria), or if the collapse of the Levant's first urban settlement system was the result of environmental or social factors. The extent to which recent development has adversely affected diminishing archaeological resources in the region is equally unknown, but impacts the ability to address questions about the past since damaged sites yield far less viable information. A large body of accurate, regional archaeological site data from the northern Levant is needed to address these issues, but this region has been largely cut off from archaeological research for more than a generation because of wars and political conditions. To address these problems, this proposal seeks funding to support archaeological site prospecting and condition assessment with two methods that utilize Landsat TM, ASTER and CORONA imagery from Lebanon and southwestern Syria. The causes of the EBA collapse will be assessed through statistical analysis of settlement pattern data derived from remotely sensed data, compared to the much better-known settlement systems in the southern Levant. If climate change is a factor in the EBA collapse, changes in northern and southern settlement trajectories should be similar across the Early-Middle Bronze Age transition. There should be expansive evidence of settlement pattern changes in the Levant (e.g., abandonment, site size decreases, etc.). The project will use supervised classification and other image analysis software to find
archaeological sites from space and compute precise site location and area dimensions. Site polygon centroids will be used to perform a nearest-neighbor analysis to match remotely-sensed sites to published site names, correct their point coordinates, and record site sizes, using a published inventory whose site locations were recorded only to the nearest kilometer. Collected over a period of about thirty years, satellite imagery can document changes in land cover and development on archaeological sites. Modern site damage will be assessed by comparing the development on sites from CORONA images of the late 1960s-early 1970s to more recent imagery, thus quantifying aspects of land cover change related to development on archaeological sites. By accomplishing these goals, the project will develop a better understanding of the impact of human activity on the environment and vice-versa over long periods of time, help quantify global land change since the EBA in the northern Levant, and further document long-term consequences of human/environmental interaction in deteriorating climate conditions. Finally, through the data sharing plan, the project makes the results available to cultural preservation planners and the public through a portal-based website, the Mediterranean Archaeology Network (MedArchNet) and its initial node, the Digital Archaeological Atlas of the Holy Land (DAAHL), which provide tools for heritage planners that aid in the preservation of cultural heritage. The project provides several specific societal benefits: 1) a deeper understanding of the first urban collapse; research methods to help identify endangered archaeological sites in many similar environments; 3) the data sharing plan helps heritage specialists mitigate the adverse impact of rapid expansion and infrastructure construction.

Compton Tucker/NASA Goddard Space Flight Center
Gordion: Mapping Past Settlements and Determining Current Threats from Land Use Changes

The site of Gordion in central Turkey is famous as the home of King Midas, whose father tied an intricate knot that was ultimately cut by Alexander the Great, but it also served as the center of the Phrygian kingdom that ruled much of Asia Minor during the early first millennium B.C. Gordion has been a University of Pennsylvania University Museum excavation project since 1950, However the archaeology site suffers from two problems that NASA technology can address: (1) critical survey errors in the hundreds of maps and plans produced by the earlier excavators, most of which used mutually incompatible geo-spatial reference systems, have prevented any systematic understanding of the site; and (2) agricultural encroachment upon the site that is compromising its archaeological integrity. We propose to address both problems in this NASA Space Archaeology proposal.

For the first problem, we propose to provide University of Pennsylvania researchers the system to rectify and incorporate all existing survey data from Gordion, including previous aerial photographs of the site, detailed site surveys, maps, and excavation plans, into a common mapping system. This will be accomplished by the use of a Geographic Information Systems (GIS) based upon a 60 cm Quickbird satellite image ortho-rectified using SRTM 30 m digital elevation data tied to a known datum surveyed last year at Gordion. This will enable the first accurate, multi-layer plan of this complex site and
make it possible to comprehend Gordion's three-dimensional development for the first time.

For the second problem of site encroachment, we propose to use ortho-rectified aerial photography from 1958 and ortho-rectified Landsat data from the 1970s, 1980s, 1990, 2000, 2006, and 2009/2010 to determine agricultural encroachment upon Gordion and the immediate surrounding area. This will document agricultural expansion into the archaeologically-sensitive area surrounding Gordion. To accomplish this we will use NASA’s ortho-rectified Landsat data for the 1970s, 1990, 2000, and 2006 as the mapping basis and compliment these data with additional free Landsat data and Turkish digitized aerial photography from the 1950s. The land use and land cover change data layers will also be incorporated into the common mapping system mentioned above.