A hundred years of lake contour fluctuation in the Hamun-i Helmand: A GIS based system for the study and the recovery of archaeological information in the Iranian Sistan (1899-1999)

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Abstract: The fragmentation of the contextual set of all kinds of information, which has not been preserved intact during the years, has always been a big limit for archaeological research.

Reconstruction is now realisable with a stochastic process, which gives a complete picture of the pertinent data by increasing approximations, because it is able to join together information and contexts otherwise scattered.

The recording, display, management and storage of data by computers, gave us the possibility to do complex analysis, which was previously impossible.

In this framework GIS are a set of instruments able to push archaeological data analysis further.

If we consider the spatial nature of archaeological data - the recording of the precise location of artefacts, ecofacts, architectural or stratigraphical units and sites - the GIS allows the archaeologist to match different types of geographic data (hydrography, soils, elevations, ...) in order to produce wide-scale analyses.

Key words: Historical cartography, Iranian Sistan, Lake fluctuation, GIS, Remote Sensing.

Introduction

Apart from a few and very exceptional cases, the archaeological record all over the world is too fragmentary, to return a direct vision of ancient lives and landscapes. The context is usually lost and it is left to the skills of specialists "to piece together the fragments of the past". Generations since World War II have been blessed by computer science, with an increasing capacity to combine vast archives of data. Reconstruction has been made possible, more recently, by so-called "stochastic procedures" which allow combining of very large numbers of operations, modeling the scattered fragments into true pictures of lost realities. As more data is introduced with different theoretical perspectivs, models can be constantly updated.

Geographical Information Systems (GIS) at present are the main instrument available from computer science to reconstruct past landscapes and human populations in their historical fluctuations, by combining data and information from maps, earth sciences, surveys and excavations.

The Iranian Sistan

The Hilmand Delta in Sistan represents a clear case of instability evidently connected to the fact that the basin is sharply limited to the west by a North-South barrier made by the front of the Palang Mountains and their piedmont colluvial fans of gravel sediments. The first noticeable difference between the Hilmand and the other systems, such as the Murghab or the Nile, is the fact that the densest settlement areas and the capital centres have always been, since the end of the 4th millennium BC, at the end of the delta system, to connect with the river as well as the huge terminal lake. The rapid build-up of sediments compels the waters to change their course several times, while a circular anticlockwise sequence of descending lacustrine basins connected with each other by spillways, like the Sheelag rud, drains overflows to the southernmost sections of the basin (fig. 1). Satellite imagery of southern Sistan indicates some six or seven overlapping delta fans, all dated by the archaeological sites to later historical times, spanning less than a thousand years in Islamic times. Even more unstable have been the southern limits of the Hamun, the largest and most perennial of the ter-

minal lakes. What is left of this ancient system, mostly dating to protohistorical times, is reduced to thin *yardangs*, columnar sedimentary residues shaped by the dominant winds. Third millennium BC soils, often black from organic content, have been detected at the top of these *yardangs* about two meters above the present level. The combined action of the expanding lake and wind erosion has lowered most of the ancient surfaces, destroying all residual evidence of the Bronze Age landscapes.

The analysis of the Aeolian deflation, as a process of concentration of the objects through the effect of the lowering of the deposit layers needs to re-evaluate the surface documentation that precedes different strategies of research. Wind and water are tireless excavators, that follow scare but precise rules (fig.2). During the 70's, American researchers like C. Redman and P. J. Watson (Redman, C. R., Watson, P. J. 1971) worked on the information drawn from the dispersion of stone artefacts on the surface of prehistorical sites in oriental Anatolia. Between 1966 and 1970, measures of the Aeolian-raining erosion rates in the Oaxaca valleys in Mexico and in the Deh Luran in Iran were made and allow Kirkby and Kirkby (Kirkby, A., Kirkby M. J. 1976.) to elaborate models of geo-morphological alteration. The archaeological team of SiS, convinced by the interest that this kind of study would present in the Sistan area, couldn't apply these methods of research, as the site of SiS was much bigger than the areas studied by the Americans and the wind and water freaks are much more powerful (Tosi, M. 1985). In 1972, they applied systematic surface survey to the areas of the site where the handicraft-quarters for lapis lazuli at SiS were discovered.

Historical cartography

The pivotal position of Sistan, among Afghanistan, Baluchistan and Iran, was critical in the power struggle between the Russian and the British empires for the region of Middle Asia during most of the 19th century. This conflict has ultimately determined the present political division of the region

H. C. Rawlinson (Rawlinson, H. R. 1873.) who visited Sistan in 1872, writes that "the comparative geography of Seistan is rendered especially difficult by the constant changes in the lower course of the Helmend, changes which are common to the deltas of most rivers; but which occur with all the greater frequency when owing to the very slight difference of level, there is no defined basin to receive the waters that are discharged". It is also useful to underline the difficulties, others British officers found in defining the course of the main river - the Hilmand - from its secondary branches, and to make the difference between artificial canals dug for irrigation purposes and natural rivers beds.

Before the work of the 1899-1902 Afghan-Iranian Border Commission, under the Head of Col. M. Mac Mahon who produced the first complete and detailed maps of the area and described precisely the circular movement of the water of the river and the lakes, we can just have an idea of the variability reading the different papers of the British officers, in particular telling about their visit to the Koh-i Kwaja mount. In 1842, Captain Conolly (Rawlinson, H. R. 1873.) needs a small reed-boat to reach what he describes as an island. Thirty years later, Major Lovett (Rawlinson, H. R. 1873.) crosses the dried lake by foot to reach the same point (fig.3)

The site

Discoveries during the last thirty years in Central Asia (particularly in the Iranian area) brought to light the antiquity of the proto-urban process in that region of the world far away from the traditional civilizations (Egypt, Mesopotamia, Harappa).

The state formation process comes for the first time, between 3400 and 3000 BC in the Nile valley, in Mesopotamia, in the plateau regions of Iran, Turkmenia, and in the Indus valley thanks to the exceptional demographic increase, to the densification of settlements along the hydrographic axes, to the exploitation of the mineral resources organized following work specialization, and to the hierarchical establishment of the society. Between 3200 and 2900 BC hundreds of little settlements are abandoned, creating for the first time a precise difference between center and periphery. In such period urban centers and as Hissar, Tureng Tepe, Namazga Tepe and Mundigak, which, together with Shahr-i Sokhta (hereafter S.iS.) will represent the "Helmand civilization".

The principal settlement of Sistan, S.iS., which represents the main center of the region during the protohistorical period, is founded on the top of the terrace, at the end of the fourth millennium.

The excavations of the Italian archaeological expedition of IsIAO (ex IsMEO) recognized during ten years of research at least 11 cultural phases (also called "structural phases") of development of the city. S.iS. represents a trade center for local and extra-regional products, but also a high-specialized place of artifact production, with entire urban and extra-wall areas dedicated to these activities.

The secondary settlements (between 2 and 6 ha.) almost all belong to the protostate phase (from 2500 BC), characterized on one side by cultural development, by technological progress and by an enlargement of the settled areas; on the other side, begins the development of a cultural preservation, due mainly to the shift of the traditional commercial and cultural axes. This process increases during the second millennium for the disappearance of the urban structures in the Iranian area. The crisis of S.i.S. in the frame of the Sistan protostate system began around the beginning of the second millennium when the town becomes smaller (from 120 ha. to 5-6 ha.) (fig. 4).

Modern Cartography and Satellite Imagery

The opportunity of using historical and modern maps, and especially satellite photos now available, in such a way as to understand the interactions between man and landscape through the reconstruction of environmental changes and their consequences on the settlement in this region, can be considered an extension of the purposes of the Italian Mission in Sistan,

helped by new technologies. The present work aims to enlarge the use of these new tools looking "backwards" to the management of documentation which was not originally planned.

We should underline that the present project has three aims:

1. recovery and management of large and varied archives of old heterogeneous data
2. integration of these data in a system of construction/ verification of hypothesis about the study of the material and of the environment
3. organisation of all the data collected in a GIS based system.

The use of satellite imagery begins after 1961 for military purposes. Since 1972, with the launch of Landsat-1 by the USA, it becomes available for scientists and the public. The IsIAO projects have made extensive use of this imagery for the study of ancient civilizations in Middle Asia and the Arabian Peninsula.

Our only serious possibility to understand the complex fluctuations of peoples and their socio-economic organization through time, since no occidental scientists can work in the area, rests only on the progress of satellite imagery for earth studies and related computer processing. The old surveyed data from the explorers of the 19th century and the archaeologists of the 20th will be projected on satellite images of highest resolution.

For the Archaeological Map of the Helmand Delta, currently under preparation in Rome and Bologna, a wide collection of maps and satellite images has been gathered to define altitude variations and geo-morphological conditions at the highest level. Recently NASA has released the collection of the first military images from the CORONA Program, that are particularly important because they date to the Sixties when Sistan was still very little developed (figs 5-6).

The idea of using GIS for the management, analysis and study of old and new data on Sistan will be directed towards reconstructing the landscape and environmental changes for the study of early civilizations in their territorial dimensions, beginning with Shahr-i Sokhta and the Early Bronze Age settlements. Central to the understanding of changes in the area is the erratic behaviour of the lake, whose fluctuations largely marked the wealth potentials of the region (figs7-8)

The methodology

Since 1978 the Italian Expedition of IsIAO could not continue fieldwork activities in the Sistan region, and from that moment the digital processing phases of the huge and heterogeneous collection of data began.

Until now, several tries of data recording, management, and visualization, such as a dedicated database, map digitization, and a Hypermedia system, developed in *ToolBook*, have been carried out.

The main aim of the project is to develop new methodological and technical approaches for the acquisition and the elaboration of a huge set of data, in order to create a Multimedia GIS for the publication of an archaeological landscape and sites, containing all the typical geo-spatial information.

The first step of this work was to realize a prototype simulation model, able to give to the user a complete vision of the problematic of this region and to allow him to analyze, through the computer, the data from an excavation nowadays inappropriate to support a normal management.

Thanks to the GIS-based system for the study of the excavation of Shahr-i Sokhta settlement and graveyard, the user can check the hypothesis proposed until now, but also explore some new hypotheses.

According to the available data, the methodology consists of the following steps:

- checking and analysis of the existing archives;
- codification and integration of the different tables in a relational system for the management of databases (RDBMS);
- digitization in CAD systems of the excavated inhabited areas and Necropolis phase maps, using different layers for each room or for each single grave and geocoding these maps;
- realization of GIS system for the analysis and the study of the excavated areas of the site;
- queries for the realization of phase, thematic and diachronic maps directly from the system (fig. 9)
- construction of a 3D model of the landscape and of the site of Shahr-i Sokhta (figs10-11);
- visualization of the site with excavation areas geocoded (fig.12);
- texture mapping of the satellite photo on the model of the site of Shahr-i Sokhta (fig.13).

With this approach, it would be possible to arrive, at the end of the data elaboration processes, or the first "virtual publication" of the protohistoric site. Moreover, the development of such multidimensional GIS, will make possible a multimedia publication of the digitally elaborated archaeological information, in order to give the scientific public the possibility of exploring and understanding the fieldwork data and information for the entire site complex (i.e.: a final CD-ROM).

Conclusion

It is clear that we have presented here only the methodological approach to the problem of recovery of data and information from an old excavation and survey. The first target we kept in mind was to find a system able to manage and record all the data and that allows us to study and to formulate some new interpretative hypotheses. Until now we have worked mainly on the collection and management of data, using GIS as the engine in which all the information will be stored, in order to allow the researchers to produce quickly and easily some basic thematic maps and to check all the data .

The next step will be the most interesting and exciting, as it will consist of the intra-site spatial analyses and of some analyses

of the working areas definition on the site. We started some analyses and at the moment the result is very satisfying, pushing us to formulate each day new intra-site analyses.

Our wish is to achieve a Multimedia GIS-based publication of the entire *corpus* of data relative to the study of the protohistoric site of Shahr-i Sokhta by next summer, which will allow us to present new and innovative hypotheses on the difficult problematic of this region.

Acknowledgement

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Figures

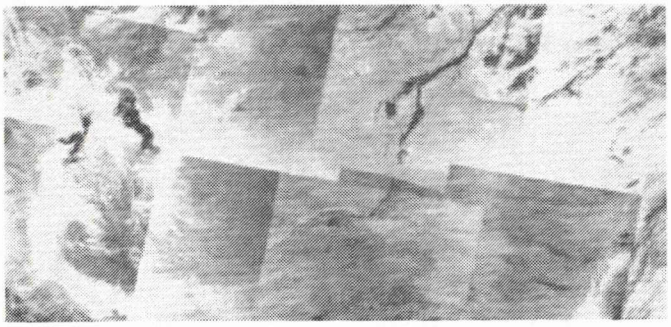

Figure 1. Helmand river view from Landsat mosaic image

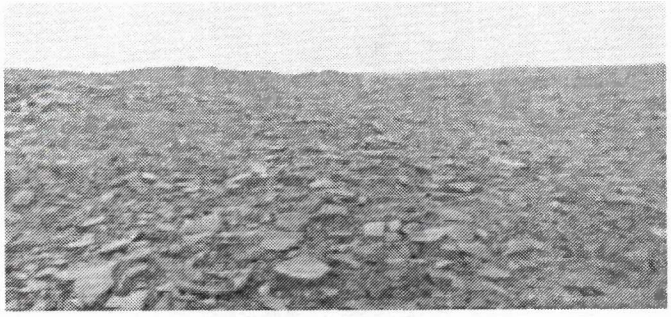

Figure 2. Potsherds on the top surface of Sharh-i Sokhta

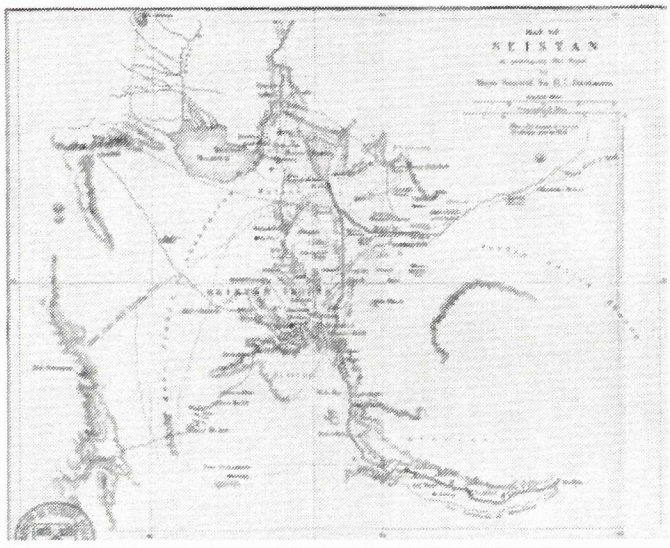

Figure 3. Historic map of Sistan by Sir H. C. Rawlinson (1873)

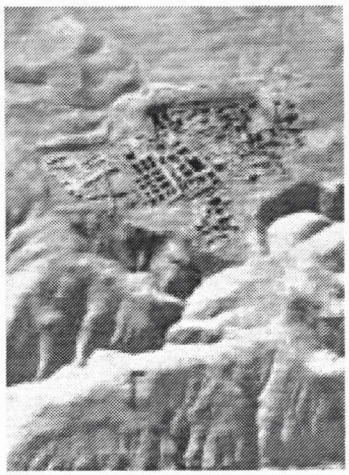

Figure 4. Areial photo of Eastern Residential Area of Sharh-I Sokhta

Figure 5. Mosaic of Corona satellite photos

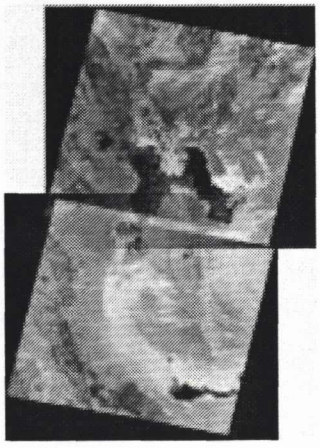

Figure 6. Mosaic of Landsat satellite photos

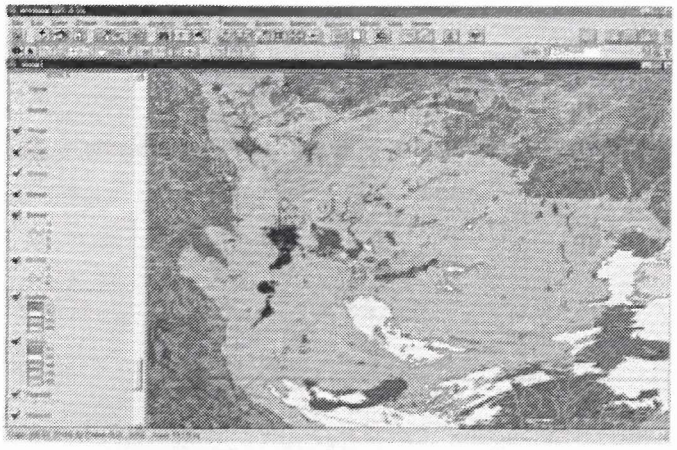

Figure 7. Reconstruction of Sistan base map with seasonal rivers net

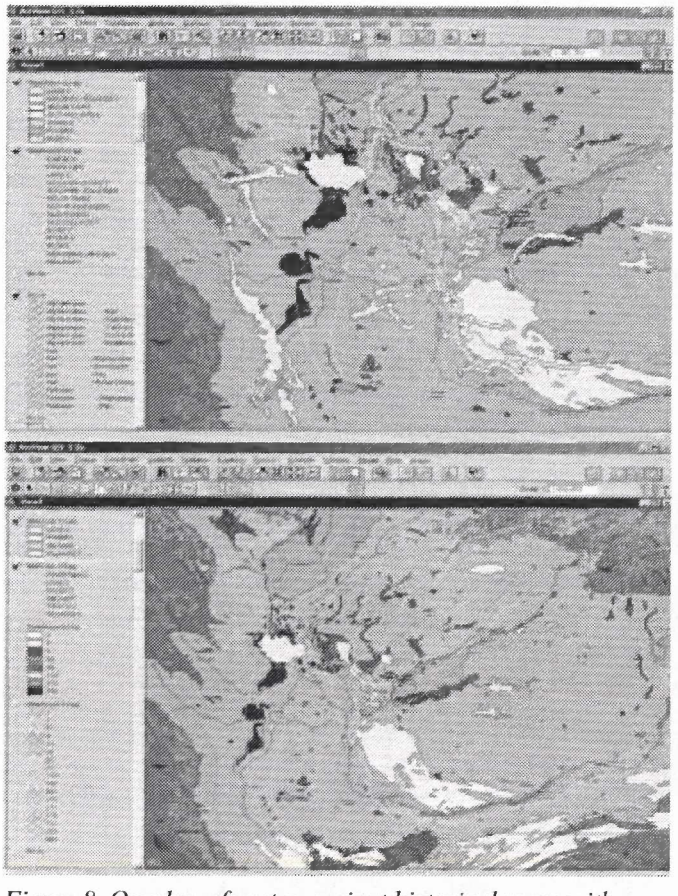

Figure 8. Overlay of vector ancient historical maps with modern reconstructed base map

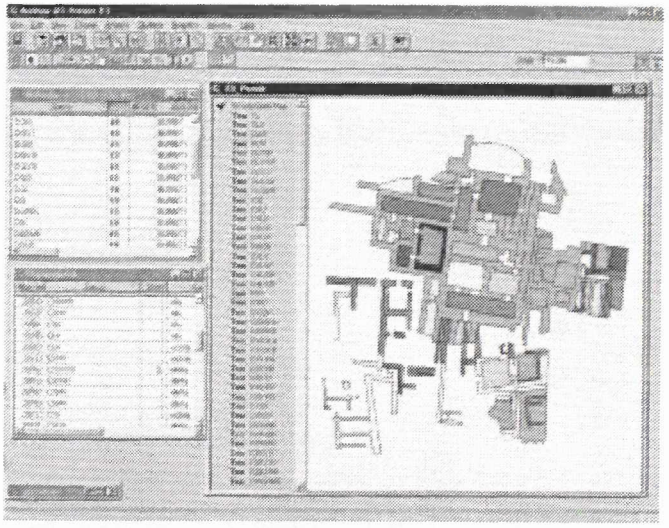

Figure 9. Queries on Burnt Building area of Sharh-I Sokhta

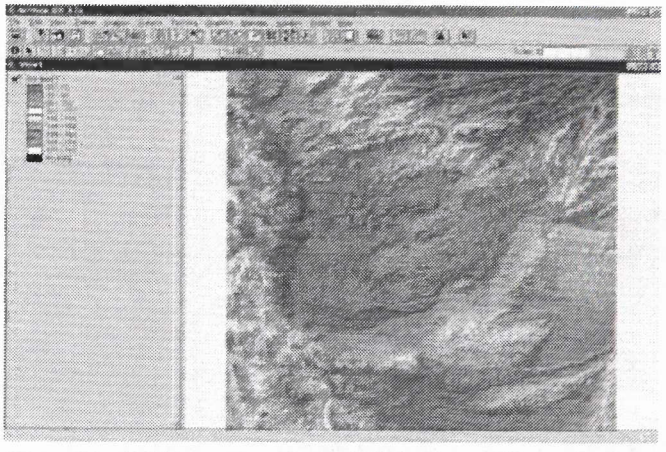

Figure10. GRID processed with 3D Analyst of Sistan basin

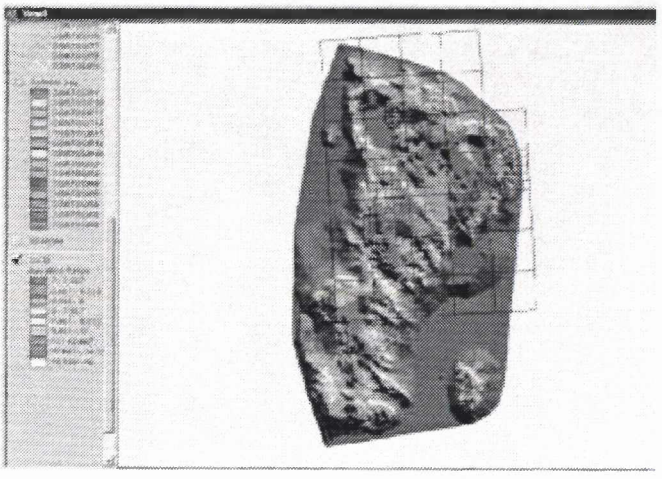

Figure11. 3D reconstruction of the site with investigated areas

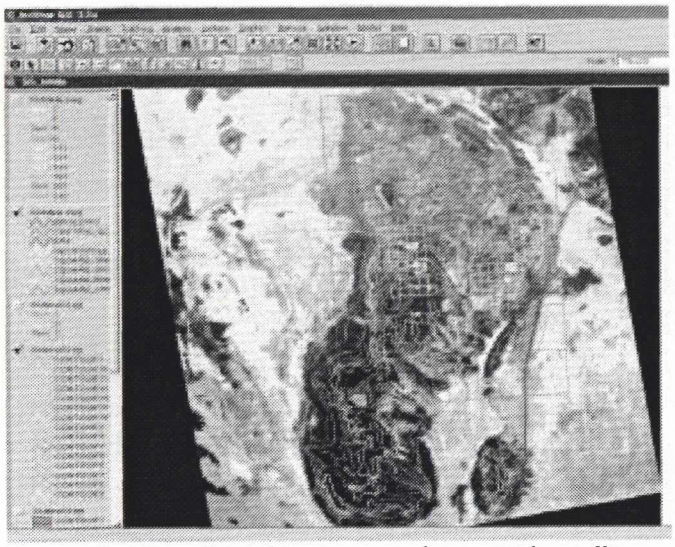

Figure12. Geocoding of the excavated areas with satellite photo

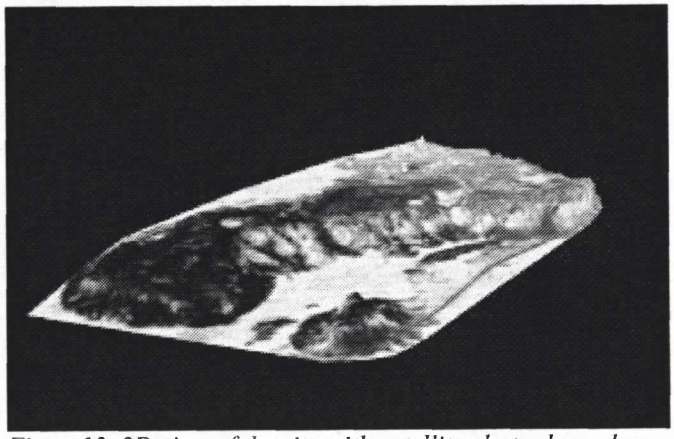

Figure13. 3D view of the site with satellite photo draped on