Global Geoglyph's Steganography: Uncovering Hidden Earth Art using Space-Based X-Band Synthetic Aperture Radar

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We propose to develop an artistic program structured around the coordinated creation and implementation of ephemeral geoglyphs. These geoglyphs must be conceived as steganographies, so that they can only be seen and read through the use of an X-Band Synthetic Aperture Radar satellite. The defining characteristic of these space systems is the ability of the X-Band to penetrate dry sand and snow, therefore revealing geoglyphs below them. These geoglyphs remain invisible to any other satellite or aerial image in the visible range. This is a new form of steganography never used before. In our project we plan to use the TerraSAR-X, TanDEM-X and PAZ Synthetic Aperture Radar satellites.

Nomenclature

SAR	=	Synthetic Aperture Radar
TSX	=	TerraSAR-X satellite
TDX	=	TanDEM-X satellite
TT&C	=	Telemetry, Tracking and Command
NOAA	=	National Oceanic and Atmospheric Administration
INTA	=	Instituto Nacional de Técnica Aeroespacial
ESA	=	European Space Agency
DLR	=	Deutsches Zentrum für Luft- und Raumfahrt e.V.
MSP	=	Maspalomas Space Station

I. Introduction

WE would like to present a project that includes two innovations: the development of a new form of artistic expression and the application of the aerospace technology necessary to accomplish such artistic expression.

Our project makes use of ancient as well as today's most advanced technologies. It will involve ingenuity, human labor, raw materials, orbital mechanics, artists, aerospace engineers, satellites, stones, snow, sand and an electromagnetic pulse with a frecuency of 9.6 GHz.

With our project we hope to lend a voice to the ones who need it the most and are least able to express their needs. We have the technology at our disposal, a technology that only a few years ago was reserved for the use of governments and the military, but one that we can now use to voice the concerns of different collectives around the globe in an uncensored manner.

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In the following sections we will present our artistic proposal and the technology necessary to carry it out. As far as we know ours is a new way of creative expression never used before.

II. Our Proposal

As written above one of our aims is to create a global creative space uncensored. To achieve this goal we propose a global artistic project of collaborative and collective art. Implementing a structure with several coordinated teams engaged in the same artistic proposal in different parts of the world. This proposal takes the form of geoglyphs conceived as steganographies.

A geoglyph is a large design or motif, generally longer than 4 meters, produced on the ground, and normally formed by elements of landscape such a stones, water, soil, etc. Namely a large-scale drawing on the surface of the Earth.

There are ancient and modern geoglyphs. Many are of uncertain origin. Maybe the best known are the Nazca Lines in Peru. Others have led to startling theories. None was made to be contemplated by a single person. And once finalized all of them were left on the ground. But we are going to hide them.

Steganography is the art and science of writing hidden messages in such a way that no one, apart from the sender and the reader, suspects the existence of the message, a form of security through obscurity. The word *steganography*, whose etymological origin is Greek, means "concealed writing" and the first references that we have come from Herodotus (440 BC) who tells the story of a message carrying a warning to Greece about Persian invasion plans. The message was tattooed on the shaved head of a slave and was hidden by the hair that afterwards grew over it. Finally it was delivered by shaving the hair again once the slave had reached the receiver.

As in the Herodotus story, we want to tattoo the surface of the Earth, by drawing geoglyphs and covering them afterwards. Our ink is going to be either water or stones that we will place under the Earth skin, that being the dry sand of a desert or the snow covering the ground. That will be the way by which our geoglyphs become steganographies, hidden drawings that can only be seen and read through the use of an X- Band Synthetic Aperture Radar Satellite. Nobody will be aware of them except those who perform the action.

Geoglyph is the ideal format since we need a size big enough for the satellite to be able to capture on one hand and because it must be a site-specific ephemeral art to fit into our theoretical proposal on the other.

As we said before we hope to lend a voice to the ones who need it the most and are least able to express their needs. The framework of a global creative space uncensored must be defined necessarily under a strong social and political commitment. Subjects related to "human rights", "ethnicity" or "environmental" are especially suitable to be implemented with our proposal.

For our project we have made the decision to start working for "women´s rights". We pretend to emphasize the fact that there are still too many women who cannot express themselves freely. And that is simply unacceptable. This is a subject that affects us all so it has to be accomplished collectively.

Collaborative and collective art practices have proliferated around the world over the last years. There is a shift from a concept of art as something envisioned beforehand by the artist and placed before the viewer, to the concept of art as a process of reciprocal creative labor[1]. Furthermore nowadays to conceive an artistic creation whose only purpose is aesthetical is simply not enough. Plus differentiation of "aesthetic" and "ethical" criteria in the evaluation of artistic production is a high point in contemporary art debates, and a matter of research among scholars.

What we want to implement is a global artistic project of collaborative and collective art focused on women´s freedom of speech. This will involve coordinated artistic interventions by different teams in different countries, aimed at making geoglyphs depicting iconic images related to women´s freedom of speech. Once done these images must be hidden under the dry sand or the snow and thus become steganographies. In this way we are able to create an uncensored space for expression that extends across the globe, involving different cultures and countries.

In order to collect the global art work hidden under the dry sand or snow all around the Earth we will take advantage of the only technology capable of such a feat: a constellation of space based X-Band Synthetic Aperture Radar satellites.

III. The Technology Behind: Space-Based X-Band Synthetic Aperture Radar

Our project requires a technology capable to meet the following requirements: must be able to acquiere images globally and be unhindered by frontiers, must have a high resolution in order to resolve geoglyphs of sensible dimensions, must be able to capture such images covered by dry sand or snow, and have to do so in a short timeframe. Those constraints leads us to use a constellation of X-Band Synthetic Aperture Radar satellites.

A. Synthetic Aperture Radar and X-Band

Synthetic aperture radar (SAR) provides a powerful tool for Earth observation from space. The method is based on a satellite sensor in the microwave frequency range, which illuminates the Earth's surface with short pulses.

Therefore SAR is an active survey method and measurements are not dependent on daylight and weather conditions. Usually the synthetic aperture radar can be operated in several imaging modes and offers a wide field of application, for example in hydrology, geology, climatology, oceanography, environmental monitoring, disaster monitoring and research in remote sensing techniques.

To obtain the highest possible resolution from space the aperture synthesis has to be applied. The targets are illuminated several times in one measurement cycle and the signals returned are correlated by their amplitude and phase. Afterwards the data points are treated as if they were gathered by one long antenna.

This procedure is called the aperture synthesis. Synthetic aperture radar offers the possibility of obtaining very high-resolution radar data from space, as the distance between sensor and targets should require that an antenna length of several kilometers would be needed for a resolution of 1m, but by SAR this length is reduced to 5m.

Space based SAR systems use different wavelengths depending on the use planned for them. In order to have a very high image resolution the use of X-Band is the best option. It offers the capacity of images resolution of under one meter. Space based X-Band SAR images have been already used in the field of space archaeology[2] and geologic studies[3].

It is also known that microwaves signals have a penetration depth in materials that is a function, among other factors, of the frecuency of the microwave signal and the composition and humidity of the material being illuminated by such electromagnetic wave[4].

The space based sensors that we intend to use have a frecuency of 9.6 GHz (X-Band), and they give us a resolution better than 1 meter[5,6]. On the other hand such a high microwave frecuency has a penetration depth on dry sand of the order of 0.3 m and of several meters in dry snow[7], such as in the Antartic firn[8].

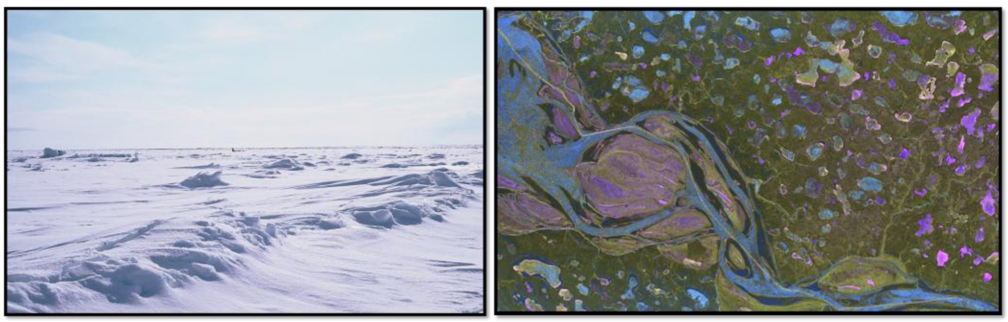

Figure 1. Optical vs TSX (X-Band SAR) image of the snow covered Mackenzie River, Canada (DLR).

In Figure 1 we have an example of the ability of SAR images to penetrate several meters of snow and record the features hidden below.

B. Space Systems: TerraSAR-X, TanDEM-X and PAZ

Several X-Band SAR space systems are already available, or will be in the near future, for civil use (COSMO-SkyMed, TerraSAR-X (TSX), TanDEM-X (TDX) and PAZ). For our project we intend to use TSX, TDX and PAZ satellites. From late 2014 onwards these three satellites will be flying in the same orbit, working as a constellation.

Figure 2. PAZ SAR satellite (HISDESAT).

TSX, TDX and PAZ share a common platform and SAR instrument imaging modes. TSX and TDX were entirely built by Astrium GmbH at its Friedrichshafen facilities in Germany. PAZ platform and part of its instrument were also built by Astrium GmbH but the front end of its instrument was designed and built by EADS Astrium in Madrid, Spain.

TSX was launched in June 2007. TDX was launched in June 2010 and PAZ will be launched in October 2014. The main parameters of the TSX, TDX and PAZ missions are listed in the following table.

	TSX	TDX	PAZ
Height	4.88 m	5 m	5 m
Width	2.4 m	2.4 m	2.4 m
Launch mass	1.230 kg	1.330 kg	1.321 kg
Orbit height	514 km	514 km	514 km
Inclination	97.4º Sun syncronous	97.4º Sun syncronous	97.4º Sun syncronous
Orbit Tube	250 m radius	250 m radius	250 m radius
Imaging capability	300 s/orbit	300 s/orbit	300 s/orbit
Launcher	Dnepr-1	Dnepr-1	Dnepr-1
Launch date	15 June 2007	21 June 2010	October 2014
Life time	5 years (consumables 7 years)	5.5 years (consumables 6.5 years)	5.5 years (consumables 7 years)
Radar frequency	9.65 GHz	9.65 GHz	9.65 GHz

TSX, TDX and PAZ active sensor is a high frequency X-band SAR that can be operated in several different modes and various polarizations. The Spotlight, Stripmap and ScanSAR modes provide high-resolution images for a detailed analysis, as well as wide swath data whenever a larger coverage is required. For instance using the high-resolution Staring Spotlight mode it is possible to achieve a spatial resolution better that 1m (in some cases close to 25 cm resolution). Additionally several incidence angle combinations are possible and double sided access can be realized by satellite roll manoeuvres.

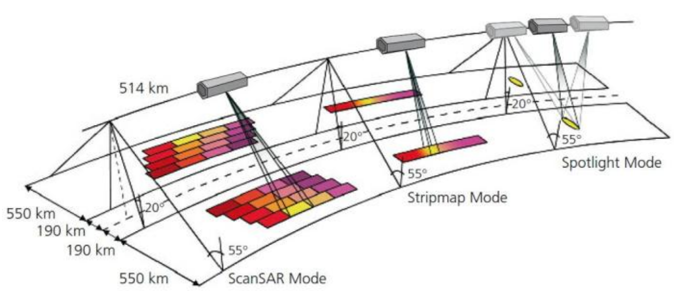

Figure 3. PAZ SAR imaging modes (HISDESAT).

Basic products from TSX, TDX and PAZ are delivered in different imaging modes:

1) Scan SAR mode: 18 m resolution , 100 km x 150 km scene size
2) Wide Scan SAR mode: 40 m resolution , 270 km x 200 km scene size
3) Strip Map mode: 3 m resolution, 30 km x 50 km scene size
4) High Resolution Spotlight Mode: 1m resolution, 5km x 5km scene size
5) High Resolution Staring Spotlight Mode: 0.25 m resolution, 4km x 3.7km scene size

The TSX and TDX ground segment is provided by DLR at the site of Oberpfaffenhofen near Munich. Operations of TSX and TDX are performed by the German Space Operation Center. Payload data downlink reception, processing distribution and archival as well as the delivery are performed by the DLR Earth Observation Center.

The PAZ ground segment is provided by INTA at its sites of Torrejón de Ardoz near Madrid and Maspalomas in the Canary Islands. Mission and engineering operations of the PAZ satellite are performed by HISDESAT.

Payload data downlink reception, processing distribution and archival as well as the delivery are performed using the abovementioned PAZ ground segment.

For our project we intend to task the TSX/TDX/PAZ constellation with the acquisition of images in a high resolution mode (either High Resolution Spotlight Mode or High Resolution Staring Spotlight Mode).

IV. Implementing a Radical New Way of Creative Expression: Art + Aerospace Technology

To carry out our project we have to display both engineering and curatorial abilities. First of all we have to set a plan effective enough for a global artistic intervention. We have designed a scheme structured around seven different steps or phases.

A. Phase 1: Choosing iconic images

This is fundamentally a curatorial task. We have to select which is going to be the image or images that best represent what we want to express. Our starting point is that we cannot use most of the basic elements of visual arts because the radar does not distinguish them. So we cannot think in terms of color, volume, textures or gradients.

Our images have to be formed just with lines or flat shapes. Somehow those are the elements used by the traditional tattoo, so we turn again to Herodotus. And because of the size, taking into account that the SAR sensor will resolve objects with a resolution of the order of 1 meter, we cannot think of something extremely detailed or complex.

So considering all these factors we have opted for either an abstract symbol or a word, both with simple shapes but complex and powerful meanings. If we choose a word we have to determine in which language or languages is going to be written (one or more, modern or classical, most spoken or minority language…), any of these possibilities gives a different nuance.

And finally since we will undertake our project in different parts of the world we can conceive a serial work of art representing the same image at each place or conceive a single work of art extended all over the countries involved.

B. Phase 2: Selecting the locations

The defining characteristic of the X-Band SAR is its ability to penetrate snow and dry sand therefore revealing geoglyphs below them. So we have to locate our geoglyphs either in arid desert areas or in high snow cover areas. The X-Band penetration is several meters throught snow and up to 20 cm through dry sand.

If we work in desert areas geoglyphs will be hidden under the sand, so unless you make use of a X-Band SAR satellite they remain non-existant. See the figure below (figure 4) for sand deserts suitable as canvases for ephemeral geoglyphs steganographies.

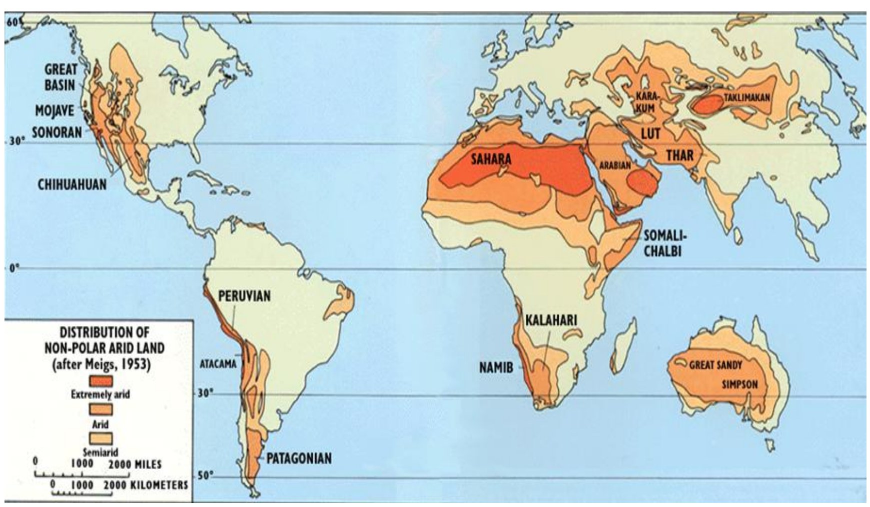

Figure 4. Distribution of Non-Polar Arid Land (Meigs, 1953).

If we choose hiding geoglyphs under the snow we have to take into account the seasonal global snow coverage. A useful tool for planning the creation of the geoglyhps under the snow is the data available at the web of the U.S. National Ice Center (see figure 5).

With the data from the U.S. National Ice Center we can select the most suitable sites and the time of the year when it will be possible to perform the artistic intervention by a local team of artists and collaborators.

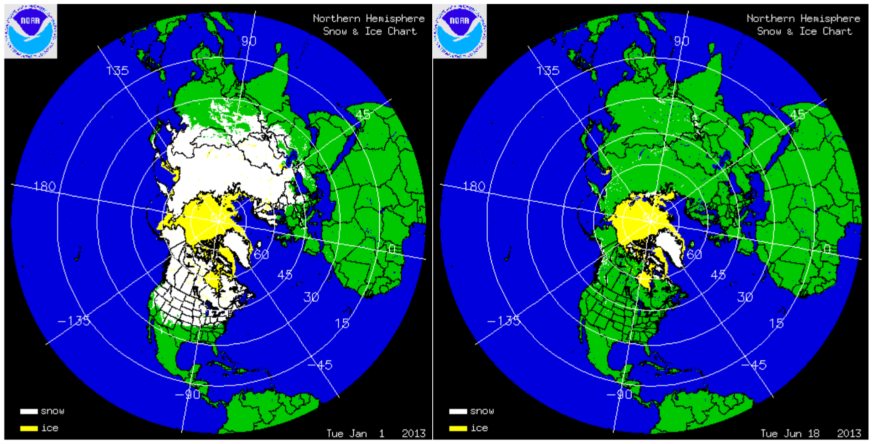

Figure 5. Northern Hemisphere snow and ice chart (1st January 2013 and 18th June 2013). NOAA.

We are always looking for remote areas in order to do our steganographies without or as few as possible spectators.

An additional advantage of Space-Based Radar is that it has been designed to carry out its task independent of weather conditions and illumination. This is of great importance when planning a synchronously artistic global project. We do not have to worry about cloudy skies, foggy days or dark nights.

C. Phase 3: Raw materials

One property of a radar sensor is its ability to differentiate between materials, surfaces or soils. It has already been used to uncover ruins under deserts or ancient dry riverbeds under the sand. Differences in soil humidity will show up in radar images and we can use this property to our advantage in the creation of geoglyphs.

To create our geoglyphs we can choose between a wide range of materials but since we will abandon them they have to be environmentally friendly. We will work with materials that can be naturally found in the area such as stones, water, sand and gravel.

Thus geoglyphs will be made of raw, natural, accessible and ecofriendly materials.

D. Phase 4: Teamwork

One of the cornerstones of this theoretical proposal is the teamwork. As a collaborative and participative work of art the performance and the work process are as important as the physical piece of art that will be the end result. This project aim to be another attempt to rethink art collectively and to return to the social[10].

In this regard we will try whenever possible to work with teams of local people sensitive to women´s freedom of expression. Each team must be able to work in the field autonomously. The entire project we will be coordinated by a central team.

We propose an artistic intervention performed synchronously within a global project. This involves actions produced on the ground, in different parts of the Earth, in different countries, taken by different teams, all of them involved in the project.

Broadly speaking this project will involve local people, artists, engineers, suppliers, promoters and spectators.

E. Phase 5: Timing

Because of the nature of the materials that we are going to use and also due to the working conditions we need to be specially careful planning our artistic interventions. Some of our geoglyphs are going to be ephemeral and their lifetimes could be from hours to months depending on the material chosen for that specific site. So we need to be aware of the time needed to complete the artwork, the permanence of that artwork and the time of acquisition of the image by the satellite.

One of the main advantages of using the constellation of TSX/TDX/PAZ satellites is that the mean revisit time is under 24 hours, so any location on the globe can be acquired in any given day. We will use a really flexible technology to acquire our hidden geoglyphs no matter where they are located.

F. Phase 6: Data collection and processing

The SAR data taken by the TSX/TDX/PAZ constellation of satellites are stored onboard in solid state mass memories aboard each satellite. All this art will be downloaded in different ground stations depending on the satellite that was tasked with the acquisition of each image.

The SAR data acquired by the PAZ satellite can be downloaded either in Torrejón de Ardoz Control Center (Madrid, Spain) or Maspalomas Control Center (Canary Islands, Spain). In the next figure (figure 6) it is shown the coverage area corresponding to Torrejón de Ardoz Control Center and Maspalomas Control Center and the 15 m antenna that will receive the data. When the PAZ satellite passes above those coverage areas it is possible to download the data that was stored in the solid state mass memory onboard the PAZ satellite.

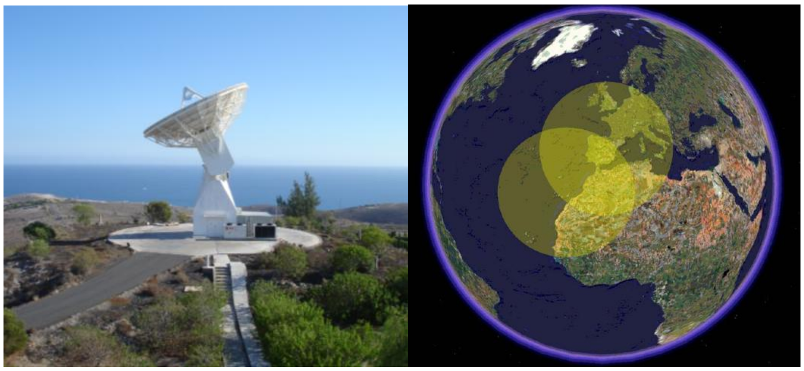

Figure 6. TT&C Antenna(15 meter), Maspalomas Space Station Canary Islands, Spain (ESA). Coverage of PAZ Satellite TT&C Control Centers: Torrejón de Ardoz (Madrid, Spain) and Maspalomas (Canary Islands, Spain) (HISDESAT).

The SAR data acquired by the TSX and TDX satellites can be downloaded in the Neustrelitz Station (Germany) that belongs to the German Space Operations Center.

Once the SAR data is downloaded from the TSX/TDX/PAZ satellites it will be processed in a few hours and archived in electronic format at the Torrejón de Ardoz site (Madrid, Spain) and at the DLR Earth Observation Center in Oberpfaffenhofen, Germany. From those sites the images can be shipped electronically to anywhere in the world. Now we have the images of our hidden geoglyphs ready to be exhibited.

G. Phase 7: Exhibition

In line with the interdisciplinary character of this project the images could be exhibited in traditional venues (art galleries, art museums) as well as in scientific or technological sites (planetariums, science museums, space control centers).

Location wise we contemplate two different approaches: a centralized exhibit as well as a distributed one. Given the electronic format of the images they can be easily transmitted and once on each exhibition venue they can be exhibited as large printouts, with computer screens or video projectors. In such a way every exhibition venue will have at its disposal all the images of every site that has participated in the collective project.

Besides the actual images of the hidden geoglyphs we foresee to present graphical documentation of the whole process involved in the creation of each individual artwork.

Furthermore we would like to complement each radar image of the hidden geoglyphs with an optical one of the site where the geoglyph is hidden. We think that the comparison of both images will act as a powerful metaphor of the issues that nowadays face women's freedom of expression worlwide.

V. Conclusion

We have presented what we think is the first application of Space-Based X-Band SAR to the field of Art. This new form of steganography enables a type of Art for collective participation with social commitment. This is a new artistic tool that can be an useful and effective instrument for different collectives or groups to express themselves freely and globally, thus generating a global creative space uncensored. We have presented a new artistic process and technique, environmentally friendly and sustainable using raw and natural materials.

We are reinterpreting a creative act performed by traditional methods with renewed artistic values, using for social purposes a technology initially developed for governmental or military needs, and in the process connecting two fields wich have remained traditionally apart: art and aerospace engineering.

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