

Google Under-the-Earth: Seeing Beneath Stonehenge; using Google Earth as a Tool for Public Engagement and the Dissemination of Archaeological Data

Key Words

Google Earth, Archaeology, Virtual Globe, Web GIS, Public Engagement, Stonehenge Riverside Project, Survey, Spatial Data, Seeing Beneath Stonehenge, Landscape, Excavations, 3D Reconstructions, Open Source.

Abstract

This paper focuses on the use of Google Earth as a tool to facilitate public engagement and dissemination of data. It examines a case study based around one of the largest archaeological investigations of the Stonehenge landscape, the Stonehenge Riverside Project. A bespoke layer for Google Earth was developed to communicate the discoveries of the research by creating an engaging, interactive and informative multimedia application that could be viewed by users across the world. The paper describes the creation of the layer: Google Under-the-Earth: *Seeing Beneath Stonehenge*, and the public uptake and response to this. The project was supported by a Google Research Award, and working alongside Google enabled a 'free to download' platform for users to view the data within in the form of Google Earth, as well as the integration of a variety of applications including: Google SketchUp, YouTube, and Flickr. In addition, the integration of specialist software, such as Esri ArcGIS, was fundamental to the integration of the spatial data gathered by the project. Methodologies used to create the application are documented here, including how different outputs were integrated such as geophysical survey, 3D reconstructions and landscape tours. The future possibilities for utilising Google Earth for public engagement and understanding in the discipline are examined.

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1. Introduction

In an increasingly digital age, the public have more ways than ever of accessing information, and the use of such media to disseminate archaeological content has become widespread (Bonacchi 2012; Richardson 2013). It would now be highly unusual to find a major archaeological project that does not have a variety of associated digital outputs to encourage public engagement including social media streams, websites and blogs providing regular updates on exciting new finds and discoveries.

Underlying this trend is a long standing commitment towards public engagement that is integrated into the very ethos of the archaeological discipline. A commitment that is perhaps in part co-related and inspired by the presence of a very large non-specialist community who have a strong desire to find out more about the latest discoveries, see sites, and to get involved in a wide variety of ways (Aitchison and Edwards 2008; Aitchison and Rocks-Macqueen 2013; Morrison 2008). Within the UK, the rise of the 'impact agenda' across the Higher Education sector in the context of the Research Excellence Framework (Hefce 2011), and the government promotion of the 'Big Society' (Woodhouse 2014) have only sought to fuel activities that look to increase public involvement.

With the intensification and pressure in the 'desire to engage' it may be somewhat surprising that some of the most commonly used and freely available forms of digital engagement have not become more widespread within the archaeological discipline. This paper focuses on one of those tools, Google Earth, and examines the use of this software in archaeology.

1.1 Google Earth

Google Earth was launched in 2005 (Google 2005) and to date over 1 billion people across the globe have downloaded it (Google 2011). As well as providing detailed satellite and aerial imagery, the platform provides the user with a web-based geographical information systems (GIS) tool, whilst allowing the import of external data sources in a Keyhole Markup Language (KML) format, an Extensible Markup Language (XML) based script, that aids the user in managing three-dimensional geospatial data in the software (Stefanakis and Patroumpas 2008). Google Earth also allows the user to integrate a number of interactive features such as 3D buildings, place markers, image overlays and virtual tours. This functionality provides a powerful tool that can be used to display and disseminate information and data. Within the application itself, Google Earth provides base mapping in the form of high-resolution satellite imagery from multiple time periods. There are also ten primary data layers for users to use and explore including: Borders and Labels; Places; Photos; Roads; 3D Buildings; Ocean; Weather; Gallery; and Global Awareness.

Google Earth first entered use in archaeology as a prospection tool where it provided imagery for sites where remotely sensed data was missing or hard to access (Beck 2006; Myers 2010; National Geographic 2006; New Scientist 2011; Sadr and Rodie 2012; Scollar and Palmer 2008; Ullmann and Gorokhovich 2006; YouTube 2014.) In recent years, the most common use of Google Earth in archaeology is rapidly becoming one of dissemination. A variety of projects have started to post layers containing basic information on cognate groups of archaeological sites. Examples include those created by the Archaeological Institute of America for the United States and Canada [hyperlink to <http://www.archaeological.org/news/aianews/6871>]; the Atlas of Rural settlement in England GIS [https://www.english-heritage.org.uk/professional/research/archaeology/atlas-of-rural-settlement-gis/]; and the Defence of Britain Archive [hyperlink to <http://archaeologydataservice.ac.uk/archives/view/dob/>].

The potential for Google Earth in archaeology was recognised early on by Ur (2006) who noted the strength of the new software lying at its interface with students and the interested public, and its use within the classroom. Since this time, continual improvements and updates have seen a rise in the possibilities of it as a data dissemination and engagement tool for archaeology. With an ability to reach mass audiences, it has been noted how Google Earth crosses several key thresholds in communicating archaeological information, taking it beyond the realm of conventional spatial data and geographic information systems, and engaging more complex dimensions of human perception and aesthetic preference (Beck 2006; Sheppard and Cizek 2009; Ullmann and Gorokhovich 2006). A particular strength was the ability to provide a way of visualising and interpreting landscape and archaeological sites by contributing to an appreciation of the wider geographical context (Beck 2006).

Google itself has been keen to encourage data dissemination via Google Earth, and created the Google Faculty Research Awards program which aims to 'identify and support world-class, full-time faculty pursuing research in areas of mutual interest' (Google 2014). A suite of grants have resulted in a variety of science based projects being created for Google Earth which primarily seek to disseminate information about a specific subject, whilst providing a spatial context within the virtual globe. The Google Earth Gallery [hyperlink to <http://www.google.co.uk/earth/explore/gallery/>] and Google Earth Outreach pages [hyperlink to <http://www.google.co.uk/earth/outreach/stories/showcase.html>] provide repositories for users to download and engage with these data.

Within the Google Earth Gallery there are over 150 projects within the 'Culture and Society' and 'Historical' categories. The majority are focused on cartographic and geographic

information, and those that link directly to archaeological sites are rare. Situated within the Outreach pages, a notable exception is the Global Heritage Fund [hyperlink to http://www.google.co.uk/intl/en/earth/outreach/stories/showcase.html#kml=Global_Heritage_Fund], with interactive layers that can be opened within Google Earth to display text based information, images and polygons of heritage sites and monuments found in the Americas, Asia and Pacific, Europe, Middle East and Africa. There are also a few sites that are hosted outside of Google. Examples include: the Archaeology of Lower Egypt projects [hyperlink to <http://google-earth-kml.blogspot.co.uk/2008/04/archaeology-of-lower-egypt.html>], and the reconstruction of proto-historic Māori land use in the Banks Peninsula, New Zealand [hyperlink to <https://gsa.confex.com/gsa/2013AM/webprogram/Paper229175.html>].

The ever increasing quantities of primary digital data being collected directly by archaeologists in the field, coupled with the desire to further communicate and engage about discoveries to the public suggest that Google Earth is perhaps now more than ever an exciting medium with which the archaeological community could engage with more fully. This view is explored using a case study based on the creation of *Seeing Beneath Stonehenge* [hyperlink to <http://microsites.bournemouth.ac.uk/seeing-beneath-stonehenge/>]. A project funded by a Google Research Award and focused on disseminating the results of the Stonehenge Riverside Project (Parker Pearson 2012).

2. The Stonehenge Riverside Project, and Google Under-the-Earth: *Seeing Beneath Stonehenge*

The Stonehenge Riverside Project undertook one of the largest set of coordinated investigations into Stonehenge and its wider landscape (Parker Pearson 2012). Initiated in 2003, it comprised six years of excavations and surveys, with over 60 trenches excavated at 17 different sites and monuments (Parker Pearson 2012). The project changed the way in which this landscape is understood today, and the results have had a major impact on the content of the interpretation and exhibition at the new Stonehenge visitor centre. The ground breaking discoveries made included the remains of Neolithic houses at Durrington Walls, and Bluestonehenge, a stone circle discovered at the West Amesbury end of the Stonehenge Avenue. In addition, the project also excavated some of the major sites and monuments located within the wider landscape, including the Stonehenge complex itself, the Greater Cursus and Woodhenge (Parker Pearson 2012; Thomas *et al.* 2009).

The project captured the imagination and interest of the public. Over 20,000 individuals visited the excavations during six years of fieldwork, and a number of television

documentaries were aired across the globe coupled with widespread international newspaper and magazine coverage (Alexander 2008; Sturcke and Kennedy 2009; British Archaeology 2010). On completion of the fieldwork much of the immediately publically visible aspects of the project inevitably disappeared, and final written outputs are by necessity of the post-excavation processes several years in fruition.

In order to continue disseminate findings to the general public whilst the final publications were completed, a new approach was necessary. The end of project fieldwork in 2009 had seen the creation of an archive of nearly 100 Gigabytes of data. This ranged from traditional forms of archaeological recording, and importantly an extensive set of spatial data from aerial photography and geophysical surveys, to excavation locations and feature mapping. Primarily organised within a project geographical information system, these spatial datasets were essentially complete, but had not been previously seriously considered for use as part of outreach or engagement activities in their own right. Funding was secured in the form of a Google Factual Research Reward to convert much of the spatial data into a format that could be viewed in Google Earth, allowing the public to explore the interim project findings for themselves via an interactive multimedia layer known as *Google Under-the-Earth: Seeing Beneath Stonehenge*, which can be explored by users across the globe through the use of the World Wide Web.

3. Creating *Seeing Beneath Stonehenge*

Seeing Beneath Stonehenge contains a range of data sets including: geo-located trench outlines and excavation plans; descriptive text and images that explain what was discovered during the excavations; spatially accurate geophysical survey plots; and geo-located 360 degree panoramic photographs of the archaeological sites and excavations. A number of 3D reconstructions of what some of the sites may have looked like based on the excavation plans, as well as other media resources such as videos visualising 3D laser scans of stone holes at Bluestonehenge were produced as additional material. The additional functions in Google Earth were also utilised by the application such as the development of KML Tours. These allow the user to 'fly' through the landscape whilst being provided with written or narrated descriptions and interpretations of what they are observing.

[Video 1]

Video documenting the functionality of Google Under-the-Earth: *Seeing Beneath Stonehenge*.

<http://www.youtube.com/embed/FpN-gCOmXIA>

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<iframe width="560" height="315" src="http://www.youtube.com/embed/FpN-gCOmXIA"
frameborder="0" allowfullscreen></iframe>
```

A number of different data sets and methodologies were employed when creating the different layers that make up *Seeing Beneath Stonehenge*. The following sections seek to examine the methodologies used, and where relevant note any recent changes that have altered these processes.

3.1 Google Earth as a GIS

Prior to incorporating any external data sources a large amount of content can be created using Google Earth itself. Here we document the usability and functionality of Google Earth as a GIS, as well as the ability to integrate other features within it.

3.1.1 A Web Geographical Information System

Google Earth uses Simple Cylindrical projection with a World Geodetic System 1984 (WGS84) datum for the imagery base, and provides latitudinal and longitudinal information about any location the user is interested in. Google Earth also allows the user to locate an area of interest by searching the name of a location, as well as by known coordinates, making it easier for people with less mapping and GIS knowledge to navigate around a landscape. Google Earth utilises the web to integrate other online resources such as the Google Search Engine, Google Images, Picasa Images and YouTube.

Google Earth also provides the user with basic vector tools, allowing the creation of points, polylines and polygons as KML files through the 'Add Placemark', 'Add Polygon' and 'Add Path' tools. These allow the user to place points, draw lines and fill polygons in areas of interest, as well as allowing the user to edit the names, views and styles of these features. Within this application these tools were used to highlight the location and layout of a number of the monuments found throughout the Stonehenge landscape, as well as providing annotations of particular archaeological features and locations (Figure 1). It should be noted that this method of selecting areas by eye was only used within the Landscape Tours (see Section 3.1.2). All of the archaeological information from the SRP Project was imported from GIS and derived directly from primary data such as site plans and total station records. [Figure 1].

Image taken from *Seeing Beneath Stonehenge* showing the use of the polygon and polyline tools found in Google Earth.

As well as allowing the user to edit the style of these features, Google Earth allows the integration of Hypertext Markup Language (HTML) coding to include dialog boxes within these KML files. This creates a text based dialog box that appears once the feature is selected by the user, providing further detail and interaction within the Stonehenge Riverside Project (Figure 2).

[Figure 2].

Image showing the use of HTML coding included within a polygon produced for the Greater Cursus.

Finally, similarly to other GIS systems, Google Earth provides the user with a layers and folders management interface that allows the user to place different data sets within folders. These folders can then be toggled on and off, depending on whether the user wishes to display the data or not (Figure 3).

[Figure 3].

Data folders found within the *Seeing Beneath Stonehenge* KMZ.

3.1.2 Landscape Tours

Beyond its use as a GIS, Google Earth provides the user with a number of additional interactive features. One of the main features used within *Seeing Beneath Stonehenge* was the function that allows users to create tours. The 'Record a Tour' tool allows the user to record the movements they make within Google Earth, providing an interactive way of displaying material at different locations throughout the landscape. The user is able to 'fly' from site to site, as well as open dialog boxes and follow paths created within a project. In addition to opening dialog boxes, the use of XML coding within the software enables the user to integrate MP3 recordings, providing an opportunity to create narrated tours. To prevent projects from becoming too large in file size, Google Earth utilises its web connection to connect to the MP3s from an externally hosted source.

For *Seeing Beneath Stonehenge*, two 'Landscape Tours' were created with both text and narrated content, with the aim to educate the user about a number of sites and monuments investigated by the Stonehenge Riverside Project (Video 2). The MP3s used for this

application are being hosted on the Bournemouth University server to ensure long term maintenance and availability.

[Video 2]

YouTube video of the narrated landscape tour for *Seeing Beneath Stonehenge*.

http://www.youtube.com/embed/PIej_SLG7vU

```
<iframe width="560" height="315" src="http://www.youtube.com/embed/PIej_SLG7vU"
frameborder="0" allowfullscreen></iframe>
```

3.1.3 Embedding

The integration of HTML coding into points, polylines and polygons created within Google Earth and the external sources drawn from the web by the software, provides an opportunity to embed a number of external media resources. The two main services used for this application were those provided by YouTube and Flickr. This saw the creation of a number of videos visualising 3D laser scan data recorded at different sites during the excavations. These were then uploaded to YouTube which provides an embedding code that could be pasted into a Placemark in Google Earth itself (Figure 4). As well as this, photographs taken during excavations were also uploaded to Flickr. The embedding codes provided by Flickr were then copied into dialog boxes that in turn displayed these images (Figure 5). These embedded images were also used in trench descriptions, providing a visual representation of what was found at each site. Trenches will be discussed further in section 3.2.1.

[Figures 4 and 5 retrospectively]

Image showing an embedded YouTube video within a Placemark in Google Earth.

An embedded image hosted by Flickr within a Polygon drawn in Google Earth.

3.2 ArcGIS™

A commercially available GIS package, Esri ArcGIS 9.x, was used by the Stonehenge Riverside Project Data Manger to manage and manipulate the spatial data gathered by the

project. This section will document the methodologies used to export the different layers that were used within *Seeing Beneath Stonehenge*, as well as identifying other alternative methodologies that could now be used.

3.2.1 Excavation Trenches

Trench outlines were one of the first data layers to be exported into Google Earth. The data archive contained a number of iterations of the same trenches, as different parts of the same trench had been excavated during different seasons. Using ArcGIS, all of the outlines were exported to a new geodatabase and the maximum extent of each trench was then digitised. New attribute fields were added to provide additional information about the trench history, including excavation start and finish year, the site code and a summary of the main discoveries within. The embedding codes for individual photos of each trench were also included from Flickr, allowing images to appear underneath the descriptions once these trenches had been selected within Google Earth.

To export these features into Google Earth, an extension downloaded from the Esri Support Centre website was installed and used to convert the geodatabase into KML format. This extension was developed by the City of Portland, Bureau of Planning and allowed for the export of any point, polyline, or polygon dataset, in any defined projection, to KML (Esri 2010). During this process, a number of export options were available. The most critical of these was the *Coordinate System Transformation Method*, where the GIS layer was converted from British National Grid, OSGB_1936 into the coordinate system used by Google Earth, Simple Cylindrical projection with a WGS84 datum. When no transformation method was used, a vertical and horizontal difference was recorded of 100m and +50m respectively, due to different coordinate values on the ground in the input and output geographic coordinate systems. Testing of the various transformation methods established a maximum horizontal inaccuracy of 2.5m and a maximum vertical inaccuracy of 16m. An assessment of the accuracy of the different transformation methods could be undertaken due to the 2005 historical imagery in Google Earth which showed a number of open excavation trenches. By overlaying the differently converted trench outlines, measurements could be made to determine the most accurate. The chosen transformation method was OSGB_1984_Petroleum, which had a horizontal inaccuracy of 0m and a vertical inaccuracy of +0.5m (Figures 6 and 7).

[Figures 6 and 7]

Historic imagery provided by Google Earth showing the 2005 Larkhill excavations.

Imported trench outlines from ArcGIS placed over the historic imagery from Google Earth, also showing the trench description and photo embedded from Flickr of the Larkhill excavations.

Further options enabled the export of a KML Layer Description and Feature Descriptions. Information from the geodatabase attribute fields were used to create the latter, which included the Trench ID, Site Code, excavation summary and embedded photos. The layer was automatically added to Google Earth and saved as a KML file (Figure 7).

In recent years the further development of ArcGIS has seen this process become less complicated with the introduction of the 'Export to KMZ' tool. In addition, open source software such as Quantum GIS also provides an alternative to exporting shapefiles into Google Earth. One consideration of these latter developments is that previously it was possible to select which attributes to transfer, as well as their order. Currently both software systems automatically transfer all attributes, and therefore a bespoke shapefile would need to be created to define both content and order of display.

3.2.2 Archaeological Features

Once the transformation parameters for the trenches had been determined, the same processes could then be applied to convert archaeological features. To create this information, a number of excavation plans were geo-referenced and digitised within ArcGIS. Once completed these then had information added to them within the attribute tables (e.g. feature type and associated context), and were exported through the process described above (Figure 8).

[Figure 8]

Digitised plans of the Neolithic houses found within Durrington Walls within Trench 1.

3.2.3 Geophysical Survey

Earth resistance and fluxgate magnetometer survey was conducted over several sites during the Stonehenge Riverside Project including: Durrington Walls; Larkhill; the Palisade; the Stonehenge Avenue; Bulford; the Greater Cursus and West Amesbury. The results of these surveys were archived as georeferenced (British National Grid) tiff images (GeoTiffs).

Theoretically, it was possible to import these images directly into Google Earth as GeoTiffs. However, these do not display background layers as transparent, which was important as many geophysical plots are irregularly shaped, and areas of 'no data' would show up as white. Therefore, a different approach was used. Using Corel Paint Shop Pro Photo X2, each geophysical plot was cropped to the survey edge. The cropped image was then saved as Portable Network Graphic (PNG). The PNGs with areas of 'No Data' were set to display as transparent, letting the underlying imagery show through. However, this process lost the georeferencing information associated with the images. To re-locate them within Google Earth, the outline of the survey data was traced as a polygon shapefile in ArcGIS and exported as a KML file, using the same OSGB_1936 to WGS84 transformation method outlined in Section 3.2.1. The modified PNG image was then added to Google Earth using the 'Add Image Overlay' tool. The image was then positioned to match the appropriate polygon shapefile. Once complete, the image was saved as a KML file within Google Earth. Again, new versions of ArcGIS 10 have allowed this process to be sped up using the 'Export Map to KMZ' tool. There are however, some issues with this approach when it comes to the resolution of the exported image, and the original method described above provides an improved end result.

3.3 Trimble SketchUp

SketchUp is a free to use software that allows the user to create accurate 3D models from spatial data gathered within the field. Designed by Google to be integrated with Google Earth, SketchUp provides the user with the functionality to geolocate a model in a spatially correct location as well as providing the correct topographic representation found within Google Earth itself. In 2012, SketchUp was bought by Trimble Navigation, a survey instrument and software manufacturer, along with the online 3D warehouse associated with it. To date, the software remains free to use and Trimble have committed to invest and grow the product, although it is unclear how this change may affect the use of this product in the future.

3.3.1 Creating 3D Models from Spatial Data

Google SketchUp 7.1 was used to create 3D reconstructions of the Southern Circle, Bluestonehenge, and one of the Neolithic houses discovered at Durrington Walls. To ensure these contained the correct coordinates when placed within Google Earth, SketchUp 7.1 provides the user with a 'Get Current View' tool. This allows the user to take a screen grab of their current view within Google Earth and place it within SketchUp, georeferencing anything that is created within that project. The advantage of this tool lay with its ability to display previously imported KML shapefiles in Google Earth, overlaying the satellite imagery.

By importing a number of digitised excavation plans of the different sites, the user can identify exactly where the reconstruction should be located, ensuring an accurate model. Recent updates to both SketchUp and Google Earth have meant that the functionality described above is no longer available, but is included here for completeness.

The plans for the Neolithic house platform and Bluestonehenge derived from digitised excavation records created as part of the Stonehenge Riverside Project. However, the data used for the Southern Circle saw a combination of the plan of the eastern half of the monument, recorded during excavations by Wainwright between 1966 and 1968 (Wainwright and Longworth 1971, Fig. 9), and the plans of the western half, recorded by the Stonehenge Riverside Project in 2005 and 2006 (Figure 9).

[Figure 9]

Combined plan of the Southern Circle indicating the parts from the Stonehenge Riverside Project and those taken from Wainwright and Longworth (1971 Fig. 9).

All three models saw an element of interpretation shape their appearance, in particular that of the Neolithic house, which drew from artistic interpretations and excavation plans detailing the location of the postholes. However, both the Southern Circle and Bluestonehenge drew from scientific information recorded during their excavations to try to recreate what they may have looked like. All the section drawings of postholes excavated at the Southern Circle were measured and averaged out to gain an average depth for each ring of postholes. These were then multiplied by three, to gain a standard height for each ring of posts (Gibson 2000). As the whole of the Southern Circle had not been excavated there were a number of postholes which looked to be missing. As a result these were placed within the model but were labeled as 'speculative'. Similarly, research was also undertaken into the standard heights of the bluestones currently standing at Stonehenge to ensure an accurate representation of how Bluestonehenge may have looked (Figure 10).

All three models were created using simple geometry tools and given textures such as stone and wood through those made available in SketchUp. Once complete, the models were exported as Google Earth KMZ files and placed within the application as part of a 3D Models layer.

[Figure 10]

The reconstruction of Bluestonehenge created in SketchUp7.1, and geolocated correctly within Trench 51 at the end of the Stonehenge Avenue.

3.3.2 SketchUp 3D Warehouse

As well as creating a number of its own models, the application also included two reconstructions of monuments that had already been created and shared on the SketchUp 3D warehouse. This website provides a repository for all SketchUp users to share their work and download other models that have been created. Those used for this application were Woodhenge, created by Henry Rothwell, and Stonehenge itself, created by Tom Harvey.

3.4 GigaPan

During the 2009 field season the robotic camera system (Gigapan Epic) together with a Canon Ixus digital camera, was used to capture 360° panoramic images of sites and monuments found across the Stonehenge landscape. Photographs included the excavations on the Bluestonehenge, as well as the wider landscape. The location of each panorama was recorded using a differential Global Positioning System (dGPS). Panoramas were created using the Gigapan stitching software, and were uploaded to the Gigapan host website together with a description of the subject and key words. Using the dGPS derived coordinates (accurate to $\pm 3\text{cm}$) each panorama was geolocated within Google Earth via the GigaPan website tools. Each of these was then saved as individual KML files, which were then merged to create one layer file for the entire panorama data set.

On completion, the material for *Seeing Beneath Stonehenge* was combined into a series of layers entitled: Landscape, Trenches, Geophysics, Videos, 3D Models, Gigapan and Archaeology. The creation of these was done deliberately to mimic the functionality of the original primary layers in Google Earth (see Section 1.1), with the aim of leading to a coherent and streamlined end user experience (Figure1, Video1).

4. Release, Uptake, and User Feedback

Seeing Beneath Stonehenge was released for general download in November 2011 [hyperlink to Seeing Beneath Stonehenge download page]. Embedded within a bespoke webpage, with associated social media feeds and further information about the Stonehenge Riverside Project, it is currently hosted on Bournemouth University servers. On release it received an immediate enthusiastic response with over 8000 downloads from over 100 different countries within the first seven months. A social media campaign utilising

Facebook [hyperlink to <https://www.facebook.com/SeeingbeneathStonehenge>], Twitter [hyperlink to <https://twitter.com/UnderStonehenge>], and Youtube was run at the same time. In this initial phase the promotional *Seeing Beneath Stonehenge* video posted on Youtube [hyperlink to <http://www.youtube.com/watch?v=FpN-gCOmXIA>] received over 23,000 hits, and there were over 300 active social media participants on the other channels.

In order to investigate what the potential impacts were of engaging with the content posted by the project within the Google Earth layers, a short user questionnaire was embedded within the host webpage [hyperlink to https://www.surveymonkey.com/s/beneath_stonehenge]. This also gave the project an additional vehicle to receive further information about ease of use of the site, and areas for potential future development. Social media was used to drive participation and 142 responses to the questionnaire have been received. The majority of participants were from the United Kingdom (68%). The European Union made up 5%, and 16% came from a wide variety of other countries including Canada, the United States of America, Japan, and Yemen. A number of respondents (11%) did not provide a geographic location.

4.1 The Influence of *Seeing Beneath Stonehenge* on Users

In order to gain a baseline indication of interest levels before engagement, respondents were asked to rate their interest in Stonehenge and the wider landscape prior to using the application. The data discussed below are taken from the 121 questionnaire responses that included an answer to *all* of the quantitative questions discussed below.

Question 1 - Before using the application how would you describe your interest in Stonehenge and its landscape? (1 'no interest' to 10 'very interested')

Interest Level	Total Response
1-5	39%
6-10	61%

Respondents were then asked about the impact of the application on their overall interest in the monument and landscape, and whether this would affect them in finding more out about past societies, and the past in general. The following data include a total response, and for comparison the 1-5 (Group A) and 6-10 (Group B) interest groups as determined by Question 1 above. It should be noted all respondents were given the same questions in the same order regardless of their answer to Question 1.

Question 2 - After using the application how would you describe your interest in Stonehenge and its landscape? (1 'no interest' to 10 'very interested')

Interest Level	Total Response	Group A	Group B
1-5	7%	11%	5%
6-10	93%	89%	95%

It is clear when comparing the data obtained from Questions 1 and 2 that interaction with *Seeing Beneath Stonehenge* has had a significant impact on users. Respondents record a substantive rise of over 30% in levels of interest at 6 or more, *after* having used the application.

In Group A, 91% of respondents recorded an increase in interest with use of the application, with an average increase in score of over 3 points. It could be argued that as these participants originally gave themselves lower scores and therefore had comparatively more of the 1-10 scale to use. However, the jump in response is striking, and also very consistent between users in this Group. The remaining few respondents in Group A recorded no change between Questions 1 and 2.

In Group B, 39% of users recorded an increase in interest after using the application, with a lower average of just over 1.5 points each. In comparison with Group A, the main difference is that 47% of these users gave the *same* value for each Questions 1 and 2, with 28% made up of those who gave the maximum score of 10. A small number of users in this Group did record a drop in interest (14%), but only by 1-2 points. Examining the free text comments associated with these latter responses, it is interesting to note that they all indicate challenges with technology (see Section 4.3).

Question 3 - To what extent has this application enhanced your understanding of past societies (1 'no more understanding' to 10 'a lot more understanding')

Interest Level	Total Response	Group A	Group B
1-5	26%	23%	28%
6-10	74%	77%	72%

Question 4 - To what extent has this application inspired you to find out more about the past? (1 'not inspired at all' to 10 'very inspired')

Interest Level	Total Response	Group A	Group B
1-5	24%	26%	23%
6-10	76%	74%	77%

The responses to Questions 3 and 4 have a very similar breakdown and indicate minimal variation between the two Groups. It is interesting to note that respondents appear to be slightly less interested in these broader subject areas than for the monument and landscape itself.

Finally respondents were asked how the application might impact on their likelihood of visiting the monument itself. Here the results are very striking with a marked difference between Groups A and B.

Question 5 - Has the application increased your likelihood of visiting Stonehenge in the next 5 years? (Yes or No)

Answer	Total Response	Group A	Group B
No	22%	10%	30%
Yes	88%	90%	70%

A free text box was also provided to gather additional qualitative feedback, and a selection of responses is provided below.

'A great tool for aiding in the understanding of Stonehenge and its landscape.'

Questionnaire Feedback, January 2012.

'...this is an excellent use of technology. Should be a lot more like it.'

Questionnaire Feedback, February 2012.

'I'm not 100% confident/familiar using Google Earth, but the tutorial helped me get my bearings, although it was tricky at first. The best bit(s) for me were all the little pop-up insight boxes into the findings and locations. I feel I learnt a lot more even though I've visited Stonehenge twice in recent years, I learnt a few things I'd not known before. The guided audio was good too. Excellent!'

Questionnaire Feedback, March 2012.

4.2 User Profile

The project was aimed directly at the general public. Analysing the full return (142 respondents) indicates that only just over half of respondents (52%) were from those who stated themselves as having a general interest in archaeology. Many replies focused on the potential for the site to be used as an educational tool, and 21% of respondents described their interest in archaeology as being an educational one.

'Awesome project. Thanks to all you chaps. It really makes teaching A Level Archaeology a lot easier'

Questionnaire Feedback, December 2011

'If further developed this app could be a very useful tool to [people] studying, practicing or generally interested in archaeology.'

Questionnaire Feedback, January 2012.

'I used this as part of an Intro to Archaeology course this afternoon. Worked very well although the system could use something specifically designed for educational purposes.'

Questionnaire Feedback, June 2012

Although not the initial intended audience, many professional archaeologists engaged with the application (18%). The remaining 9% of respondents did not indicate their background interest in archaeology.

'This is a fantastic way of utilising the expansive volumes of Archaeological information that are often inaccessible to the general public. The application of this work not just to major sites but also to Local Authority HER databases and other information sources offers a fantastic opportunity to improve access to information to inform not just the general public but heritage professionals and other relevant industries (examination of the setting of heritage assets would be better considered if this joined up landscape approach was easily accessible). It also acts as a brilliant champion of the UKs greatest asset – its cultural heritage.'

Questionnaire Feedback, December, 2011

4.3 Challenges Experienced by Users

It is important to note that inevitably there were a minority of people who reported not finding the *Seeing Beneath Stonehenge* experience as positive as others. A few users appeared to struggle with the 'operator led' design of the application, and this normally seemed to be associated with a lack of experience of the software. Issues with iPads were also recorded

on two occasions (see Section 5.2). It is interesting to note the link between technological challenges and lowered interest response rates as observed in Section 4.2 above.

'I could not make it work. I have an educated interest in Stonehenge and want to make use of the site.'

Questionnaire Feedback, October, 2012

'cannot download to ipad2 have google earth'

Questionnaire Feedback, July, 2012

In general though, being new to Google Earth did not appear to inhibit others finding their own way through the data and landscape. The inclusion of links to tutorials and other sources of support on the *Seeing Beneath Stonehenge* website are thought likely to have been an important element in helping this.

4.4 Conclusions

The data from the questionnaire confirm the overwhelmingly positive response to the content in the application as also observed through the social media feeds linked to the Project. What is particularly interesting is the direct impact of the application on users, and the stimulation of a greater interest in the archaeology it represents. This is particularly apparent for those users who were less familiar with the site or had less interest in it to start off with (see Section 4.2). The comments associated with this Group focus heavily on learning, an interesting use of technology, and importantly enjoyment.

It is clear that there is a public demand for engaging and informative content, and that the use of technology appeals to many. It is also evident that the application has reached a more specialised audience than perhaps it was originally intentionally designed for. In particular, the educational use is an important consideration for the future, and the ability to view and interrogate data in such an interactive way clearly also appeals to archaeology professionals.

Whilst it is clear that *Seeing Beneath Stonehenge* has been very successful, it could be argued that the uptake could have been higher, given the in excess of one million visitors to the monument itself [hyperlink to <https://www.english-heritage.org.uk/content/imported-docs/education/business-management-stonehenge.pdf>]. This may in part be due to a reticence of users to interact with what might be perceived as alternative technology, and also due to the challenges in establishing and then maintaining, a new web address held on

a University server at the top of a list of hits for a Stonehenge web search. Hosting a link to the site on a central point of information about the monument would undoubtedly increase downloads. Download numbers aside, a point to note is that the application can be interrogated multiple times by the user once it is on their computer, but these use statistics are harder to define.

Finally, of considerable interest is that *Seeing Beneath Stonehenge* has also had a life far beyond the original intentions for the application. It has been extremely popular as an outreach tool for schools where it has been successfully creatively used to teach information technology, and GIS/mapping skills whilst introducing pupils to archaeology and inspiring them to find out more about the history and heritage of their local areas. Other unprompted uses have included the posting of the application by the specialist tour company Martin Randall [hyperlink to <http://www.martinrandall.com/news/79-seeing-beneath-stonehenge/>] as a pre-tour primer for their clients.

5. Discussion

The outcomes have demonstrated that even for a large scale archaeological project Google Earth provides a quick and relatively simple to use platform that can integrate a number of different data sets and media formats. In addition, 3D models and landscape tours provide additional interactive features that further the experience of the user. It is clear that this form of informative application can be successfully embraced by a 'mass audience', and is a positive example of how Google Earth and associated software and websites can be used to encourage public engagement and facilitate the dissemination of large quantities of information gathered during archaeological field work. The approach is perhaps extremely well suited to the presentation of large scale, complex and geographically dispersed research. However, despite the seemingly obvious attractions, Google Earth has not yet been fully embraced by the discipline in this way. The potential reasons for this and the future for archaeology and Google Earth are discussed below.

5.1 Software and Resources

In common with many disciplines archaeology is still struggling to keep pace with technological change and the technological literacy that by default accompanies it. However, the complexities in building a similar Google Earth application to *Seeing Beneath Stonehenge* are now much reduced and could be carried out almost entirely using open source software (see Section 3.2.1). The only exception is the inclusion of Gigapan images, but panoramic photographs can be taken from cameras and mobiles and easily uploaded. The only loss here would be the high-resolution and display properties of the former

alongside the active community which engages with this product. Online tutorials, support documents, and communities are also now readily available to help both new and more experienced users find their way. Recent work by the *Seeing Beneath Stonehenge* team with teachers and school children has also indicated that these skills can be easily learnt and developed with very little additional support. In addition, the next generation of archaeologists will have generally experienced improved training and awareness in GIS, Google products, and related software.

A greater challenge may be the time required to build a Google Earth application. *Seeing Beneath Stonehenge* was funded, allowing the employment of additional staff to develop it. Without this, it would have been extremely difficult to achieve. In addition, whilst it is now technologically easier to construct an application, unless initial thought and consideration has been given to how the data are collated additional time may be needed in development. If Google Earth is not considered at the start of project, then it may become viewed as too challenging to create later on, and the likelihood is that a way of achieving dedicated time to do so may be difficult to access

It is also important to note that since the beginning of this Project, other online tools have been developed to share and display spatial data to non-specialists. Indeed, Esri now provides a special offer for those wishing to transition from Google to Esri products [hyperlink to <http://www.esri.com/landing-pages/products/google-lp>]. Specifically, Esri has produced ArcGIS Online [hyperlink to <http://www.esri.com/software/arcgis/arcgisonline>] and ArcGIS Explorer [hyperlink to <http://www.esri.com/software/arcgis/explorer>]. The former is a web-based application where user generated content can be shared within an organisation, or the wider public. Points, lines or polygons can be embedded within a basemap selected by the creator, or end user (e.g. a satellite image or a thematic map), and attribute information can be accessed via an 'Inquire' button. Hyperlinks can also be made to other online resources and images. ArcGIS Explorer is a downloadable App for both mobile and desktop devices designed to link to ArcGIS Online and display map packages similar to the one created as part of *Seeing Beneath Stonehenge*. Point, line and polygon layers can be interrogated and their attributes read. Raster datasets can be viewed, and 3D models can be rendered.

These new online tools and products could be seen as an effective alternative to using Google Earth. However, even with the potential subscription requirements in mind, the functionality of the tools, and the ease of use need to be developed much further to make them viable options, and comparable to Google Earth. For example, the ability to create a landscape tour is not yet available in ArcGIS Explorer. A search for 'archaeology' within the

publically visible layers available on ArcGIS Online, returned 59 UK-wide datasets with 122 in total from across the globe. Of these, many were 'test' layers, indicating that whilst users are willing to try and create maps via this route, they are perhaps not yet being developed to their full potential. In addition, both products may take some time to be understood and adopted by the public as the perception of a 'Professional' application, and the associated reticence with respect to 'new' technology may detract from their uptake. Google in comparison already has an established reputation for creating easy to use, free, accessible software and is therefore likely to be adopted more readily by the non-specialist.

5.2 Mobile Technology and Google Maps

Google Earth has yet to transfer effectively to the world of the tablet and mobile, a challenge observed in the users of this project (see Section 4.3). Whilst it is possible to open *Seeing Beneath Stonehenge* on such a device, much functionality is lost. Importantly the more interpretative and engaging aspects of it such as the 3D models and landscape tours do not run. With the rise of mobile technologies there is an argument to be made that effort might be better directed on the development of Apps and other software that make use of this fast growing market (Shaw and Challis 2013). License costs are now generally more affordable and indeed free for Google based Apps. The challenge here is that technology has not yet advanced to a point where a 'user generated' product of the desired quality is easy to achieve. Therefore, specialist knowledge and possible associated finance might be required. In contrast Google Earth remains free and easy to use.

Alongside the rise in mobile technologies, Google Maps has also gained in popularity. The software has a potential advantage over Google Earth as it allows users the convenience of accessing multiple data without having to exit an individual web browser. There is 3D functionality with Google Maps. Models from the Trimble warehouse [hyperlink to <https://3dwarehouse.sketchup.com/>] are included, and Google are adding their own auto generated 3D buildings using stereo-photogrammetry from aerial imagery. Importantly though, it is still missing the ability to embed bespoke tours and the multiple layers of satellite imagery that are available in Google Earth. Issues surrounding data ownership and Google Maps are also an important consideration and are discussed below.

5.3 Data Ownership and Permanency

In addition to the challenges surrounding the creation of an application, the recent 'ownership' issues surrounding data posted in Google products have been of considerable concern to many (Gustin 2012; Pentland 2013). Hosting a Google Earth project for

download by users outside of Google may be one way to overcome this issue in the short term, and there is perhaps a greater challenge for those projects considering using Google Maps (see Section 5.2). In addition, anxiety of the permanency of outputs is a genuine consideration, both from the perspective of archiving of data content, and the time length of user viability of any application they are hosted within (Myers 2010).

Data archiving can be achieved outside of a Google Earth project by utilising providers such as the Archaeology Data Service (ADS). In *Seeing Beneath Stonehenge* data were standardised, managed and maintained following the ADS guidelines (Gillings and Wise 1999). This will ensure that ultimately data remain accessible and understandable to individuals that wish to draw from it, as well as providing data formats that can be used across a number of platforms and incorporated into other projects and software. Any standalone Google Earth application will inevitably have a limited lifespan, as new interpretations and evidence, alongside changes in technology and the way people engage with data will ultimately combine to allow the natural lifecycle of technology and ideas to take their course. An example of this is *Seeing Beneath Stonehenge* itself, which was never designed to be actively curated, and as such inevitably provides a snapshot of the interpretation and conclusions drawn by the Stonehenge Riverside Project at the time it was created. Whilst the significant majority of the application is still in date and very relevant, the Project is now considering how best to update and enhance this type of resource in light of the forthcoming concluding monographs (see Section 2).

5.4 Where now for the use of Google Earth in Archaeology?

Previous studies have already indicated that the creative use of alternative virtual applications can increase the public understanding of archaeological sites (Ch'ng *et al.* 2013; Landeschi and Carrozzino 2012). The distinct advantage of Google Earth over other software is that it has become mainstream, free to use, readily available, and accessed by millions. In addition, whether from large scale research projects, or small local investigations, all archaeological information contains a spatial context. The geospatial nature of Google Earth therefore provides an excellent platform to enable creative applications where this information can be disseminated within an interactive context that users can relate and engage with.

An alternative mode of engagement might be seen to be social media feeds and blogs. Whilst it is relatively simple, quick, and convenient to post content to a feed using conventional and mobile platforms, the information can be transient and potentially disconnected. In contrast, the very nature of Google Earth provides a way in which to aggregate and impart content in a more united way. Moving forward, advances in

technology will also almost inevitably enable us to do more with the software. For example, it is now feasible to bring 3D models into the software that have been created in structure from motion applications, although currently it takes considerable effort to do so.

Time has been identified as a serious limiting factor in the development of any future Google Earth applications (see Section 5.1). The perception of a need for a greater 'technological literacy' than is now actually required may also potentially combine with this to negative effect. In contrast to these difficulties, of considerable interest will be how the rise in community based archaeology, and synergistic 'citizen science' might perhaps have a positive impact on the uptake in the use of this software in archaeology. Many new projects have recently come on stream that aim to collate yet more digital data through community involvement, for example the recent development of MicroPasts [hyperlink to <http://micropasts.org/>].

6. Conclusions

Seeing Beneath Stonehenge was one of the first applications of its kind to incorporate such a wide variety of different types of spatial data from a single archaeological research project, whilst also making these freely accessible to the more than one billion people that have downloaded Google Earth. The results have demonstrated that the opportunities for positive public engagement are high, and there are many additional benefits that can be gained especially those associated with education. The ability of the software to enable the interpretation of archaeological sites within a wider geographical context is of great value in addition to allowing the user to explore specific sites and discoveries.

Google Earth presents a relatively easy way in which to engage with an audience that is now 'technology expectant'. Questions around the nature of data ownership and curation will continue to need to be debated, but the new generation of 'digital natives' will expect more from us, and we have yet to deliver. Whilst it is highly likely that some of these applications may be transient in their nature, value will be achieved by enabling users to make sense of complex data even if it is for a short window of time. One of the greatest challenges for archaeology in the future will be to develop ways to give meaning and narrative to the 'data deluge' we find ourselves surrounded in. Currently, Google Earth remains a considerable untapped resource with which to do this.

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