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CASE STUDY

Keeping it Real: Creating and Acquiring Assets for Serious Games

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Abstract This paper presents the data collection for a project aimed at creating a virtual game like experience of a historically significant location in Western Australia. The goal is less about just conveying a sense of the place but more about creating an accurate representation. Where data such as imagery and 3D models are used to represent features at the location are unavailable or approximate, they AQ1 remain missing rather than filling with interpretations or interpolations. The resulting virtual environment is closer to an archeological recording or database rather than simply a 3D environment one can navigate through and experience. It is proposed that the resulting virtual environment takes on an additional believability and appears more real than if it was enhanced by arbitrary modeling and generic texturing. Presented are the data capture methods employed, the limitations encountered in conducting data capture in the field, constraints imposed by current technology and finally the remaining challenges in the various technologies employed.

Keywords Virtual environments · Serious games · Virtual reality · Digital assets · Heritage data · Unity3D · 3D reconstruction · Photographic textures

1 Introduction

The wreck site of the Dutch East India Company *Batavia* (Green 1975) in 1629 has long been associated with terrestrial archaeological sites on the islands adjacent to the wreck site. Beacon Island is significant as one of the primary heritage sites

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(Green 1989) related to the event as it was the island where the majority of survivors from the wreck reached. It is known from the journal of the commander of the ship, Francisco Pelsaert, of the events that took place on these islands. Numerous people including men women and children were brutally murdered by a group of mutineers. Out of 322 people who were on board the *Batavia* when it was wrecked, only 122 people survived to reach their final destination, Jakarta.

From the 1950s Beacon Island was occupied by people involved in the fishing industry. By the beginning of the 1960s there were three families operating on the island: Martin, Johnson and Bevilaqua. Each had a separate jetty, living accommodation for the skipper and deckhands, a generator shed, workshop and 'long-drop' toilet. Problems arose between the requirements of maintaining the industry and the management of the archaeology of Australia's oldest European habitation site, including damage that had already occurred to a mass grave adjacent to one of the buildings.

Fig. 1 Aerial view of the Island from Landgate database

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The Western Australian Museum has responsibility for these sites under both State and Federal legislation. As a result of the developing problems on Beacon Island, negotiations were undertaken to relocate the fishers from the Island. While this was underway the WA Museum obtained a Your Community Heritage grant to start recording the buildings and their heritage significance. This was with the objective that when the fishers were relocated the buildings would be demolished and thus it would be important to record these buildings and the configuration of the island at the time for posterity. In 2013 The University of Western Australia was awarded an Australian Research Council Linkage grant called Shipwrecks of the Roaring 40s. One of the aims of this grant was to investigate new technologies in marine archaeology that have become available since the work of the WA Museum in the 1970s and 1980s.

It was decided to incorporate this heritage project as part of the Roaring 40s ARC grant with the idea of producing a digital 3D representation of Beacon Island and the fishing families buildings. The aim to create a virtual environment was driven by the desire to both digitally record the island before it was radically changed with the removal of the buildings and to create a platform by which the historical and future data could be placed within a geographic context. The virtual representation additionally needed to be of sufficient quality to enable it to be deployed across a AQ2 range of presentation modalities, from simple online experiences to high resolution virtual reality rooms (Fig. 1).

In exploring new digital recording and processing technologies, it was decided to ensure all aspects of the virtual representation should be derived from actual data, to avoid where possible interpolation and interpretation. Specifically, ensuring all 2D and 3D elements were based upon data recorded from the island rather than, for example, being created freehand or using generic assets.

The choice of software platform was Unity3D, a decision made due to its adoption and expertise within the research group at the time but also because it supports a wide range of deployment options relevant to the project including, but not limited to, the following:

- Head mounted displays (Cakmakci and Rolland 2006) such as the Oculus Rift or GearVR.
- High resolution stereoscopic display installations, both projector based and tiled units, for example, so called power walls.
- Hemispherical domes, both front facing iDome (Bourke 2009) and horizontally orientated domes as found in planetariums.
- High resolution immersive cylindrical displays (Reda et al. 2013) often controlled by computer clusters rather than single workstations.
- Online web page delivery.
- Deployment on at least Mac OSX and MS Windows.

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2 Digital Assets

The digital assets acquired during two field trips to the island are summarised below. Examples of each will be presented where that is possible in a 2D printed format.

2.1 Floor Plans and Building Modeling

Due to the ad-hoc nature of the buildings construction, being largely self built and randomly extended to over time, there exist no council or town planning building plans. Fortunately the designs are simple, largely rectangular rooms, doors and windows. During the two field trips the floor plans of the buildings were accurately measured, including the positions and dimensions of doors and windows (Fig. 2).

The building models for the island could therefore be accurately extruded from the plans and one of a small number of roof styles applied, again based upon

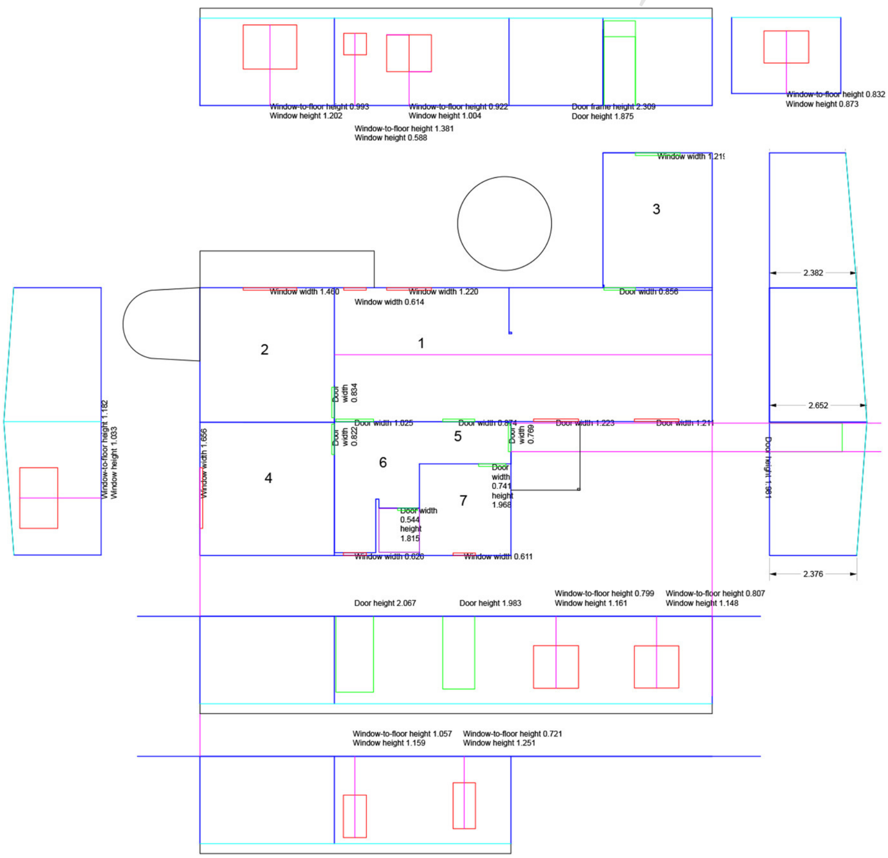

Fig. 2 Sample of exploded floor plans with measured dimensions

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measured dimensions. HDR photographs were captured from multiple heights and from multiple positions around each building, at least in so far as was possible given neighboring buildings, topology and foliage. While these were not used directly they did form a cross check of model integrity as well as identifying portions of a building that may have degraded between the two recording sessions.

Consideration was given to the possibility of photographically reconstructing the buildings from the collection of photographs captured. There are a number of entirely automatic algorithms (Snavely and Seitz 2006) and software such as PhotoScan to reconstruct 3D geometry from photographs (see later for the application of this to more organic geometry on the island). There are also human guided tools that are considered more applicable to strongly rectilinear forms found in buildings and which use the images to create whole surface textures. Two examples of this approach are found in PhotoModeller and Sketchup. However the results were found to be significantly inferior to manual models created from the plans. This is due to a number of reasons including:

- Many parts of the buildings were obscured by foliage, at least from the available camera positions and so parts of the textures could not be recovered.
- Photographs of the sides of some the buildings were not possible due to proximity of other buildings, water tanks or simply debris.
- Photographing the roofs in order to get sufficient view angles was problematic.
- The resulting mesh data can be inefficient and generally does not map logically to the physical structures.

At the end of the day, the model quality from a skilled architectural modeler was significantly better than the same time investment from a human guided reconstruction process. The accuracy was also determined to be higher since the human guided semi-automated approaches require common features to be manually selected on the photographs with corresponding pixel location and rounding errors.

Many of the above are also reasons why laser scanning (Elberink 2008) was not a viable approach. In that case the additional problems include the difficulty of dealing with point clouds in current real time virtual reality and gaming software or turning large point cloud collections into meaningful geometry. Many laser scanners with integrated cameras give colour points but the texture fidelity is significantly poorer than the photographic techniques employed here. Laser scanning would also suffer from the lack of access to many sides of the buildings.

2.2 Photographically Derived Building Textures

All textures for the exterior of the buildings were photographically captured as ortho-photos (Szeliski 2004), at least where that was possible. When oblique photos were necessary due to access limitations the photographs had shear and stretch transformations applied to make them approximately orthographic, the main error being incorrect parallax.

For non-specific textures regular tileable textures were created using patch-based texture synthesis (Efros and Freeman 2001) and applied to surfaces that didn't have

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recognisably unique features. Separate photographs, often of a whole wall or section of a wall, were used when there was a distinguishing feature to be recorded, see concrete engravings on the walls in Fig. 3.

Particular attention was made to photograph all windows, doors and other notable external features. The final 3D models had correctly dimensioned openings in the model for windows, doors and large defects but they contained no measurements of the structural elements, windows framing, window sill, door framing and so on. As with many field trips to remote locations the time on site is limited and detailed modeling was considered prohibitively time consuming. While post ad-hoc modeling of frames and lintels based upon the photographs was readily possible this was considered to be crossing the line with respect to the data based aims of the project, and would unlikely be as realistic in appearance as the photographic textures, see Fig. 4 for two examples.

2.3 Terrain maps and Topology

The overall terrain image map for the island was acquired through Landgate, the Western Australia state map archive. The island was available at 20 cm grid cells, see Fig. 1, which while adequate for aerial viewing, provides a disappointing texture map at ground level, see ground plane in Figs. 3 and 8. A subsequent field trip to the island planned to record a whole island mosaic using a drone (Turner et al. 2013) but technical issues followed by weather conditions (high winds) precluded that.

The topology of the whole island was surveyed; the spot heights were subsequently triangulated (Bourke 1989) and then converted into a 16 bit grey scale map for the Unity3D engine. The aerial texture maps were successfully registered with this topology map using 3 clear markers in both datasets, namely the cairn and two building corners from the survey data. It should be noted that there

Fig. 3 Sample of extruded buildings and a water tank

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Fig. 4 Examples of two building window textures. Both nearly orthophoto before perspective correction

was variance due to the difference in time between the aerial survey and the topology survey due to some of the more dynamic shorelines that change shape as storms pass through.

2.4 General Textures

The ground cover of the island is a combination of sands, small stones and shells, up to large coral pieces ($\sim$30 cm across). An extensive collection of orthophotos were taken for the intended purpose of tiling the topology which was currently textured with just the aerial photographs. It was decided not apply these through texture painting due to the arbitrary nature of that process because a detailed landscape categorisation was not conducted. A higher quality aerial image map may have allowed acceptable texture painting and this would significantly improve the visual appearance at ground level.

Another set of photographically acquired textures were used for such objects as the wooden structure of the jetties, metal on old crayfish pots, various pipes, exterior signs, and so on.

2.5 3D Reconstructions

There are a number of objects on the Island that could not realistically be measured and any manual modeling would have involved a large degree of interpretation and approximation. These are mainly organic forms formed from large coral slabs, they include three key objects: a 2 m high cairn referred to as Goss's monument after the

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captain of a vessel that was wrecked in the area, the remains of which may have been a small building on the east of the island and a number of fences the fishermen build around some of the dwellings.

While unsuited to manual modeling these structures are ideal for 3D reconstruction from photographs using modern photogrammetric techniques. Once the models for these are created they are either precisely geolocated based upon the survey data points or where those were not recorded they are aligned using their visible positions on the aerial image. The resulting 3D model of what may have been a small building is shown in Fig. 5. These meshes can be highly detailed with millions of triangles or down sampled to meet graphics performance budgets. The high resolution texture maps provide a highly realistic, and correct rendition even of individual pieces of coral slab.

Unfortunately while suitably accurate models of the cairn and small building reconstructed well, the coral walls did not. This failure was largely due to the inability to gain access to enough positions to achieve sufficient photographic coverage. The approach employed to representing the coral walls was to model them by hand, this is a compromise to the data based goals of this project but the implications of excluding them was considered more of a misrepresentation than creating fake models. Heights and depths of the coral walls were observed.

2.6 Environment Cube Maps

In order to provide a global context for the sky and ocean a number of environment images were created. These are generated by taking multiple wide angle photographs that are in turn stitched together to form a single seamless 360 by 180° spherical panorama and subsequently resampled into cube maps as required by

Fig. 5 Reconstruction as 3D mesh geometry and texture maps of what remains of a coral structure. Reconstructed from 220 photographs

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most game engines. Noting that for an environment map only the top 90° (horizon to north pole) is required.

These environment maps were created at various times of the day from before dawn to after dusk with another sample at midnight, see Fig. 6 for an example taken at 7 p.m. close to sunset. While only a total of 8 time steps were captured they span a single day with largely unstructured blue sky. As such they could be interpolated to provide a sample environment for anytime during that single day.

Unfortunately at the current time the environment map within the software employed cannot be used to illuminate the virtual space using global illumination techniques, at least not in real time.

2.7 Bubbles

It was recognised early in the process that the interior of the buildings were far too complicated to ever be modeled in 3D, at least not with the time and budget available. Figure 7 is a typical example of the geometric complexity found in most of the buildings. The approach taken was to capture reasonably high resolution spherical (equirectangular) panoramas from the center of every single room of every building on the island. This is exactly the same techniques as used for the environment maps. The result was almost 70 bubbles conveying a photographic sense of the contents of every room, albeit from just a single location within each room.

It was also decided to capture these bubbles from roughly 3 m equal positions along the major paths of the island in a similar way as is often done for virtual tours. In addition to experiencing the virtual 3D geometric model of the island one can jump into photographic bubbles at regular intervals and interactively navigate the view to see the island exactly as it was from that location.

Fig. 6 Sample environment map at dusk. Note only the *top half above* the horizon is used as the sky maps

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Fig. 7 Example of a geometrically complicated interior that would be extremely difficult to capture by any means

In the end this resulted in another 200 bubbles from around the island. These are incorporated into the virtual environment as inverted textured spheres that fade in when one approaches them. If the user enters the sphere then they are sucked towards the center, since that is the only position from which the spherical panorama looks perfectly correct. It should be noted that, obviously, the bubbles were positioned and aligned correctly to give a consistent experience when one moves from the 3D model to the interior of a photographic bubble and out again. Figure 8 is an example of the photographic view from within the bubble and the view of the same building in the virtual model (from a slightly different position), the semitransparent bubble is visible on the left.

2.8 Foliage

The foliage on the island consists of low and generally dense bushes, the highest of which is about 1.5 m. The 6 main bush types were identified and a statistical sample

Fig. 8 View from inside the bubble (*left*). Island virtual model showing semi transparent bubble on the left (*right*)

of branches and leaves photographed against a black background along with a scale rule, see Fig. 9. The intention was to use the structural knowledge of the particular species, for example the statistics of the branching ratios, branching intervals, thickness ratios, leaf coverage and so on to create parametric models of the plant that could be virtually grown in their respectively correct regions.

It was initially imagined that the limiting factor in achieving a virtual representation of the foliage would be the geometric cost. The parametric plant forming tools within Unity3D and other engines are sophisticated enough to deal with level of detail based upon distance. The limiting factor was rather the inability, with the tools available, to create representations that looked anything even close to reality.

2.9 Audio Recordings

Directional audio was recorded of the significant audio sources encountered on the island. These are largely the ocean waves and bird sounds, the later consisting of terns and seagulls. Full ambisonic recordings (Branwell 1983) were not made since at the time that could not be conveyed in Unity without commercial additions. Instead 4 channel directional recordings were made even though Unity can only represent omnidirectional point sources.

Within the virtual environment these sound sources were located in spatially logical positions around the island. For example the terns largely occupied the interior scrub on the island and seagulls tended to occupy the extreme points of the various jetties and beaches.

2.10 Gigapixel Images

A number of gigapixel panorama images were captured from key locations on the island. Figure 10 shows one example, a 0.9 Gigapixel image captured from the main jetty. While these were originally intended simply be used as panoramas in their own right they did provide a level of insurance if a texture asset was missed or otherwise not suitable. The resolution of the panoramas were high enough to

Fig. 9 Two samples of foliage recordings photographed to facilitate the creation of textured planes

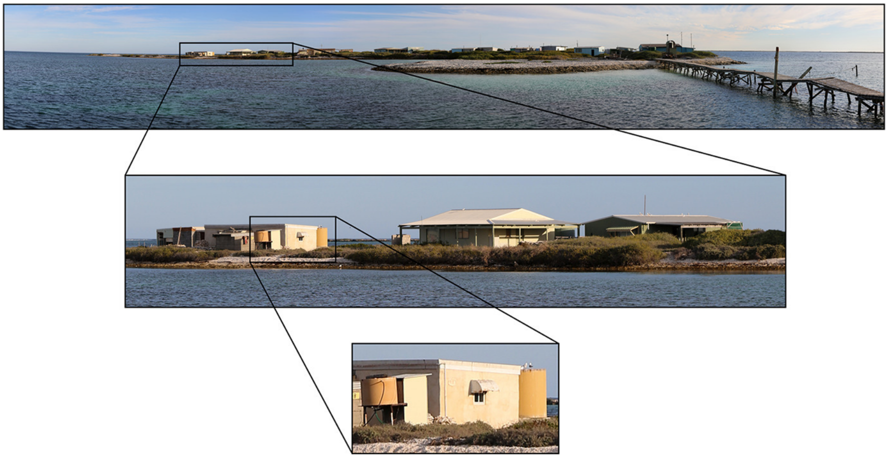

Fig. 10 Gigapixel image as backups for textures and as a more informative check on island layout

recreate the missing texture (Krispel et al. 2015). They also served as a useful check if there were questions/uncertainties of where things were located on the island, providing a faster reality check than searching through the large numbers of arbitrary located and oriented images in the photographic archive.

2.11 Challenges and Discussion

Believable representation of the foliage on the island proved problematic and is the most significant missing feature. Despite having carefully captured profiles of the plant species and categorising branching and stem/leaf probabilities, the parametric plant models created never appeared even close to the real thing. Attempts at improvements through carefully crafted, but non-parametric plants was clearly going to lead to a environment for which there would never be enough graphics power for realtime interaction. While parametric plant models often result in very believable generic ground cover in games, operating in the reverse where one has a known target plant appearance still appears to be highly problematic.

A frequent decision was when to use different types of texture, specifically, when to insist on a totally original full coverage (eg: a door), when was a tiled texture permitted (eg: boards on jetties) and when should tiled textures be used (eg: roofing iron or general rust). The guiding principle was whether the texture conveyed either more or less information that would be noticed in reality. For example, a board making up a wall that was visibly weathered compared to its neighbours compared to the hundreds of boards on the jetties that all look mostly the same. In the former situation a specific texture would be photographed but for the later a small number tileable textures would be created to give some variation but they would not be specific to individual boards.

To date game engines generally only support point sound sources. When experiencing the game the various sources are summed based upon their relative distance to the player to give a partial spatial sensation, for example closer sounds are louder. Such a model does not adequately support higher level ambisonics, such as variations to head turning, the height of a sound and other effects experienced with directional sound sources. These are not always a limitation because the gaming audio hardware may not support such effects, but in virtual reality environments those capabilities usually exist.

Audio assets, like many of the other assets are captured at a single point in time even though they are inherently time varying. The time scale of the different data types varies from years (degradation of buildings and reshaping of coast line), months (growth of foliage), weeks (bird populations especially during breeding seasons), hours (position of the sun) and finally seconds (sound of wind and waves). While the assets that change over a short time scale are no longer at the same time as the assets that occur over a longer time scale, they are still from the island. There would be no experiential difference if generic wave sounds were acquired from a digital library, and indeed no one would know the difference. For the development of this digital world there is however still a "feel good" aspect to knowing the sound scape is recorded from the location. There is invariably a positive and verbally expressed appreciation from those experiencing the environment once they are aware of this.

Given the aim of a data realistic model the final digital model file was large. Game engines like Unity3D provide various means by which the user can select levels of rendering quality given the capabilities of the hardware the game is being run on. Additionally there are tools the developer can employ to manage texture resolution and geometry fidelity through multiple levels of detail. These are however runtime choices when the large game binary is already installed on the computer. For online browser based games one would like to avoid an excessively large download period. The solution is the dynamic downloading of assets as they become required, but the current built-in support for dynamic assets proved limiting. It is accepted that for an action game that relies of fast reflex and responses that latency or performance drop while assets are being downloaded is undesirable. In the application of this type of 3D environment non-smooth actions and latency arising from internet downloads is acceptable. The dynamic database acquisition of higher quality assets during game play is part of the future work. It also opens up the opportunity to add new content as research data is acquired without the need to rebuild and redistribute a large game file.

Related to the above is that while game and VR engines provide developer tools to manage levels of detail, what one really requires is an automatic continuous resolving of geometry (Khodakovsky et al. 2000) and texture. Noting that this should be truly incremental without duplicate data being sent or reloaded. Algorithms for progressive streaming of geometry and texture are being developed but to date are not widely deployed. This is an active area of research in computer graphics.

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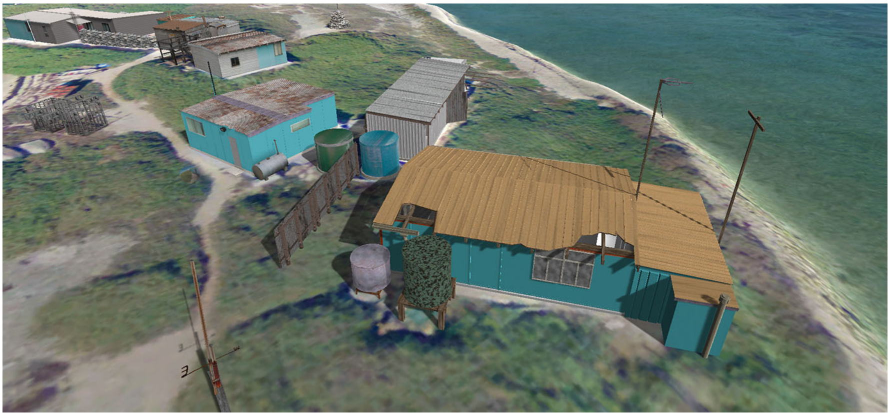

Fig. 11 Sample view while in flying mode

Fig. 12 View in flying mode showing coral cairn (photographic reconstruction) and coral walls

3 Conclusion

A goal of this project was to create a digital representation of Beacon Island that was based entirely on real data assets from the island. Since that was not always possible it forced decisions on when to make up representations (sounds, images, 3D structure) and when to only use data derived assets even though when doing so may result in a less appealing experience. The general rule adopted was to consider if the non-data based information would mislead one as to the state of the island. Selected examples might include:

- The terrain texture from aerial photography was low resolution and results in less than an ideal experience when moving around the virtual model at ground level. Higher resolution textures, while captured, were not used since the ground cover distribution across the island was not recorded.

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- If a building wall contained a feature, such a rust hole through the roofing iron, then a dedicated texture would be photographed. If there were no distinguishing features such as regular rust along a pipe then it was considered acceptable to photograph a section of the pipe and create a seamless texture that could be tiled along the whole length of the pipe. It should be noted that in no cases were generic textures use, all were photographed from the island.
- Ambient and highly transient features such as sounds and sky maps don't add anything to the representation or experience above what similar assets from a different part of the world might. For example, waves sounds compared to generic recorded waves, or a sky from somewhere else on Earth compared to one recorded from the island. There is however an intangible satisfaction in knowing and being able to convey to the participant, that those assets are from the actual place.

It is proposed, but based solely on subjective feedback at this stage, that as a result of the data focused approach, the result is a more believable virtual experience of the island, for additional snapshots see Figs. 11 and 12. Certainly the model as a representation of the state of the island before the buildings were removed is more accurate as a consequence of trying to "keep it real".

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