USE OF MULTI-RESOLUTION LASER SCANNING/WHITE LIGHT SCANNING AND DIGITAL MODELLING OF THE HISTORIC HUTS OF SCOTT AND SHACKLETON IN ANTARCTICA.

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1. ABSTRACT

This paper discusses recent laser scanning / white light scanning and modeling work undertaken on Scott's huts at Hut Point and Cape Evans, and Shackleton's hut at Cape Royds where scan data is being integrated to support multidisciplinary studies and develop interpretative models for broader public consumption. The pre-fabricated wooden huts assembled in Antarctica by Scott and Shackleton during the Heroic Era of Antarctic exploration represent one of the great episodes of human endurance and endeavour. One hundred years on these huts remain in situ in one of the most inhospitable environments on earth. Remarkably, they survive in relatively good condition; a haunting legacy of exploration. By virtue of their remoteness, the huts were not subject to major human impact since their abandonment about 100 years ago, with the exception of conservation efforts, which began in earnest about 30 years ago.

The cultural heritage significance of these sites, coupled with their inaccessibility makes them well suited to digital recording, modeling, and remote interpretation. However data acquisition in the Antarctic is complex and time consuming, and this is problematic in an environment where available operative time is usually at a premium. The use of different methodologies including recent surveys of the buildings and their unique contexts have allowed a truly accurate record of these structures, their contents and immediate environs to be produced at a variety of scales. Such a record forms an essential part in the planning and implementation of their ongoing conservation and wider scientific and educational interpretation. Dissemination of this data allows a broad spectrum of users with disparate needs to undertake specific analysis or interpretation; specialists such as: archaeologists, conservation architects, conservators, microbiologists or audiences interested in the interpretation of aspects of the cultural heritage and history of these sites. We discuss the collection and integration of multi-resolution spatial data and the specific complex data requirements of various users, which present numerous challenges when constructing and transmitting models of three-dimensional space.

2. BACKGROUND

The early expeditions to Antarctica erected pre-fabricated wooden buildings and brought in large quantities of supplies for the survival of the parties. On Ross Island, three Heroic Era huts were constructed in the early 20th century. Discovery Hut was erected at Hut Point (77·85ºS, 166·63ºE) in 1902 by the National Antarctic Expedition led by Robert Falcon Scott and served as a shelter, workshop and supply store. The hut and supplies were abandoned at the end of the expedition in 1904. The second of the Ross Island huts, Nimrod Hut, was erected at Cape Royds (77·55ºS, 166·15ºE) in 1907 by Ernest Shackleton during the British Antarctic Expedition, and subsequently abandoned in 1909. Scott returned to Antarctica in 1910 with the British Antarctic Expedition and erected Terra Nova Hut at Cape Evans (77·63ºS, 166·40ºE), which was abandoned when the survivors of the ill-fated expedition left Antarctica in 1913 (Figure 1). The huts were variously occupied until Shackleton's Ross Sea party in 1917 when they were finally abandoned. During the 1940s the huts were revisited with restoration work beginning on Discovery Hut in 1957. Discovery Hut's close proximity to McMurdo Station and nearby Scott Base has resulted in it being most affected by human impact, but all the huts have suffered impact to some degree. Since the 1960s the huts have received increased visitation from conservators, scientists, staff from the local bases, and in more recent times, increasing numbers of tourists from cruise ships.

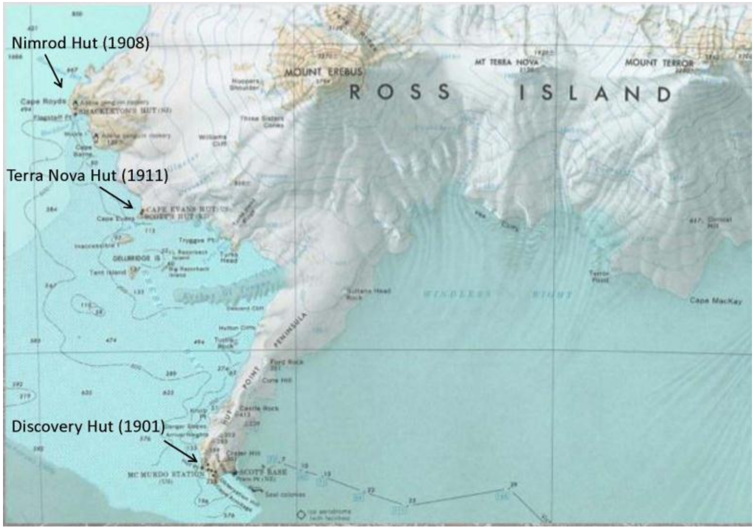

Figure 1: Location of Ross Island Heroic Era Huts, Antarctica.

3. MULTI-RESOLUTION DIGITAL RECORDING

A multi-resolution high-definition survey methodolgy using laser and structured-light scanners is a requisite to faciltate the diverse data requirements of Antarctica New Zealand Event K021, an international cross-disciplinary research team. Previous scientific data capture has generally focused on studies at the micron level, whereas the data captured for the conservation plans for the huts [1,2,3] has been recorded at a much larger scale. The two datasets however are not independent of each other. The recording of high-resolution three-dimensional digital models over which we can apply and model data taken from the various scientific analyses aids the analysis and modeling of the effects, relationships and results of the numerous causes of change. The data can be used to elucidate the impact of non-biological and biological deterioration present in the huts and artefacts, and provide high-resolution baseline as-built surveys to monitor the effects of the current and future conservation works to the historic huts. Detailed three-dimensional data can be used to create a digital inventory to track artefacts and record attribute metadata. Furthermore, high-resolution records of these structures can be developed to create accurate representative three-dimensional virtual models for interpretation. Given the inaccessibility of these sites, remote virtual interpretation becomes an necessary tool.

4. EQUIPMENT

One of the primary goals of the 2011 field season was to confirm the ability of the equipment to operate at extreme temperature ranges. Firstly, not all scanners will operate below 0^{o}C. Time-of-flight scanners in particular struggle due to the inability of the laser pump to operate in below zero temperatures. Battery life is significantly reduced in cold temperatures while recharge times are extended, reducing surveying efficiency in the field. Wind also presents problems as scanners generally require a stable platform, at least for the duration of each actual scan, and wind-blown sands and fine volcanic gravels play havoc with specialised digital equipment containing extremely sensitive optics. Snow and ice build-up on structures limits target visibility resulting in interrupted returns and obscured surfaces. All laser scanners also have to balance distance and accuracy, whereby the greater the distance, the lower the accuracy and precision due to increased laser spot size.

Structured light scanners also require a stable platform and are susceptible to interference from ambient light, which can be a problem in Antarctica in January when there is 24-hour daylight and a high albedo landscape. They are also sensitive to fluctuations in temperature; requiring recalibration if the ambient air temperature varies by more than a few degrees.

Two instruments were selected for the surveys: a Leica 6100 phase scanner for recording exteriors, interiors and topography, and a Breuckmann smart*SCAN*^{3D}-HE structured light scanner for detailed high-resolution recording (Figure 2). Although both instruments are technically *scanners* the two instruments operate in fundamentally different ways. The phase-based Leica 6100 records point clouds based on the shift in phase from the emitted and returned continuous light signal, whereas the smart*SCAN* ^{3D}-HE consists of a projector unit located in the middle of the scanner base, which based on the operation principle of miniaturised projection technique (MPT, patented by Breuckmann GmbH) rapidly projects a vast number of fringe light patterns onto the measuring object. Each end of the sensor base is equipped with a high-resolution 5 Megapixel digital colour camera, capturing every single projection point of the patterns formed on the surface of the object. A special algorithm then performs a triangulation calculation to measure the exact position of each point within the fringe pattern [4]. The recording resolution for the Leica 6100 is ≤3 mm at 90% albedo up to 50m with the ability to collect 508,000 point of three dimensional point data per second [5]. The Breuckmann^{3D}-HE can record field of views up to 1500mm with resolutions down to hundreds of microns, processing up to several million points for each scan dependent on the lenses used.

Figure 2: Exterior scanning at *Terra Nova* hut using the Leica 6100 (left) and scanning artefacts inside with the smart*SCAN* ^{3D}-HE (right).

Antarctic logistics also play a role in equipment choice. As the huts are reached by helicopter there are equipment weight limits that need to be factored into equipment selection as all camping supplies, survival and science equipment are carried. The 2011 K021 field party comprised six people, transported in one helicopter, with our equipment limited to ~640kgs sling-loaded under a second helicopter.

5. BIOLOGICAL VS. NON-BIOLOGICAL DETERIORATION

One of the fundamental research goals of K021 has been the investigation of biological and non-biological factors affecting the huts and their associated environs. These studies have focused on the evaluation of biological and non-biological deterioration [6, 7] the effects of fungi [8, 9], cellulose degradation [10], non-biological affects on the physical and chemical structure of wood [11], wood defibration [12], wood rot [13], and environmental factors that influence microbial growth in the huts [14].

Analysis of rates of wood deterioration on Antarctic structures includes the measurement of timbers on Mawson’s Hut [15, 16] at Cape Denison, and huts at Cape Adare [17]. Harrowfield [17] studied timber weathering and wind velocity focusing on the wooden huts from the British Antarctic Expidition (1898-1900) led by C.E. Borchgrevink and the northern party hut of Scott’s (1910-13) *Terra Nova* expedition. Obtaining measurements using a vernier calliper, cores, dental wax casts and analysing wind velocities and timber densites, Harrowfield concluded that differential rates of erosion had occured to exposed boards, and the primary causes of this was wind blown sand and pebbles, with variations in wind speed measured at different heights.

Wood deterioration on the huts occurs differentially, determined in part by exposure to the attributing environmental conditions and the density of the affected timber. Godden, Mackay and Logan [16] note that timbers with a density greater than 800 kg m^3 have good abrasian resistance charateristics [17]. Patterns of differential ablation are best charcterised by dense knots in the wood eroding at slower rates than the surrounding less dense areas. The process of timber erosion evident on Antarctic structures has been described by Blanchette et al.[12], where erosion occurs when areas around rings (earlywood cells) are eroded before highly lignified latewood cells. This process generally results in timber surfaces forming what is best described as a crenulated form when looking at a cross section of the surface (Figure 3).

Figure 3: Differential ablation on exterior timbers.

Studies of deterioration have more recently included the affects of conservation work being undertaken by the New Zealand Antarctic Heritage Trust [7] who are undertaking the preservation work on the Heroic Era huts on Ross Island. This conservation and mitigation work began in 2005 and has included the removal of ice in and around the huts, replacement of exterior and interior wood, installation of insulation materials, and conservation of structural elements and artefacts. Artefacts of the Heroic Era period are found in and around the huts and have been treated on site as well as at Scott Base, New Zealand and Australia [18].

Erosion rates are neither constant nor uniform throughout the structures [17, 6] and problems with the accuracy of recorded rates and estimations of erosion from previous studies, particularly with regard to data recorded from Mawson's hut, have been discussed [19]. However, the capacity to undertake accurate studies of erosion patterning and deformation modeling, especially over large external areas at the micro-scale, was limited by the availablity of suitable recording equipment during these early studies.

6. RESULTS

Complex structures like the huts with their confined interiors full of artefacts and their exteriors littered with detritus present numerous challenges for recording, not in the least the requirement for large numbers of scans to survey the complex spaces in their entirety. General interior and exterior scans were undertaken using the Leica 6100 at a spatial resolution of ~3mm, with a lower resolution of ~10mm for landscape areas. Although the huts themselves were seen as the primary survey target, time was also allocated to record the landscape around the huts where large numbers of artefacts lie in situ, and many smaller structures such as meteorological stations and instrument housings still reside. As the topography surrounding each hut in part governs the effect of the localised environmental conditions and how each hut in turn is affected, topography and locality are a significant factor in the degradation of the huts.

Surveys were undertaken from January 16-28 starting with Discovery Hut before moving on to Terra Nova (Figure 4) and then Nimrod huts (Figure 5). Further high-resolution recording of ablated surfaces was undertaken on the exterior of Discovery on return to Scott Base from the field. Scanning at Terra Nova was restricted to the recording of all exterior surfaces and associated curtilage and the localised topography due to the presence of Antarctic Heritage Trust conservators working inside the hut. One small internal area of fungal growth was recorded as well as several artefacts. At Nimrod detailed recording of the exterior, interior and topography was completed, along with high-resolution recording of ablated exterior surfaces (Figure 6) and areas of internal defibration, and Shackleton's stove. In all, each of the scan subjects comprises numerous scans of three dimensional data.

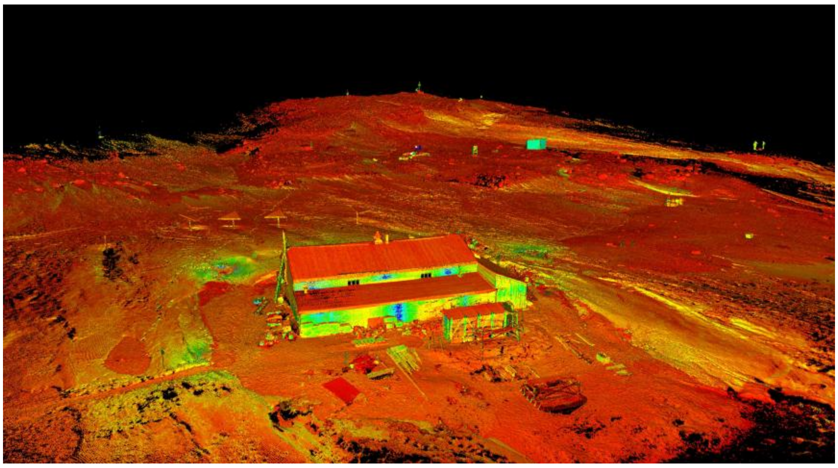

Figure 4: Registered point clouds of *Terra Nova* hut.

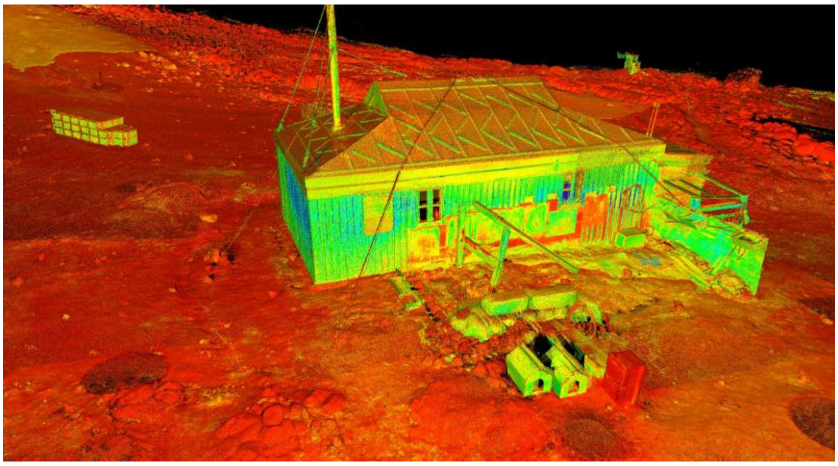

Figure 5: Registered point clouds of Nimrod hut with stables and dog kennels (foreground).

Figure 6: Section of an ablated veranda post from Discovery hut recorded with the smart*SCAN* ^{3D}-HE. Remnant paint flakes can be seen on the right hand face.

The recorded artefacts at Terra Nova included two metal food cans (one of which had been conserved, and one which had not) (Figure 7), a complex scientific instrument and a coal chisel. The cans were selected as a control study to monitor material conservation and the others were selected to test the ability of the structured light scanner to record surfaces with different form, detail and reflectivity values, while operating within a cold environment.

Utilising the Breuckmann OPTOCAT software, registered point clouds from the Leica 6100 have been integrated with the data from the smart*SCAN* ^{3D}-HE, thus creating a truely scalable three dimensional data set. Contextually, this is important as multiple micro-scale surveys can be added over time to the larger baseline data, adding to the analytical potential of the model, and future iterations of specific weathered surface areas can be layered onto the existing data without affecting the integrity of the original data.

Figure 7: Greengage can in unconserved state (left, centre) and metal scientific instrument (right) recorded with the smart*SCAN* ^{3D}-HE

7. DISCUSSION

Surveys undertaken during the January field season were designed to collect as much baseline as-built data of the huts as possible within the limited timeframe, and to record specific examples of wood deterioration. Over three days at Nimrod Hut using one scanner with a two-person crew it was possible to record an almost perfect coverage of the site and all the structures. Due to the dense assemblages of artefacts it will never be possible to get a complete, one hundred per cent coverage of the interiors of these complex structures. However it is still possible to obtain a highly detailed, precise and accurate representative record that far exceeds the detail and accuracy previously collected at any of the sites. Any gaps evident in the data can be filled during surface modelling if necessary.

The process of data collection utilising laser and structured light scanners in Antarctica was previously untested so the results provide a proof-of-concept that validates the research methodology. Baseline data that has been established during the first survey season can now be added to over successive surveys. Expanding the micro-scale recording to larger areal units will enable better long-term monitoring of the weathering of the Heroic Era structures. Repeat surveys will be used to analyse types and rates of deterioration and deformation affecting the structures, and to model the effects of conservation works on the original fabric.

The high resolution (sub-millimetre) measurements of areas of surface detoriation allows for better correlation and data integration of the disparate data collected by the K021 group. Where previous measurement of erosion and deterioration rates have tended to treat wood surfaces as planar - where erosion rates are measured as mm/year (or over larger temporal scales), and areal measurements of erosion are often described by indicating points on the structures where the most observable erosion has taken place, such as the corner or ridgeline of a building - using the Breuckmann smart*SCAN*^{3D}-HE, we can now record the true form of degrading surfaces, measuring surfaces in tens of microns. This extends to the recording of in situ artefacts.

More importantly, data collected from the two different types of instruments has been integrated to create a single scalable model where users can view data from a landscape scale down to areas of interset at the micron scale (Figure 8). Data collected previously by the project partners, such as high resolution photography, can be retrofitted to the data by draping the imagery onto the surface models generated from the scan data providing more opportnuity for scientific analysis.

Although the utility of the scanners in this harsh polar environment has been proven, some issues were encountered when undertaking the surveys. Below -10^{o}C laptops have difficulty charging, rebooting or sometimes waking from sleep mode, and the transfer of large volumes of data from scanner to laptop can be slow. Most consumer-grade hard disks are rated to -5^{o}C so laptops and scanners had to be kept warm during any disk activity. Battery life and charging times are severely impeded below 0^{o}C, requiring excessive use of generators. Constant and strong ambient light from the snow-covered terrain, 24hr daylight, coupled with light coloured and bleached timber surfaces on hut exteriors can make scanning with a structured light scanner difficult as the ambient light needs to reduced as much as possible for the projected light pattern to be recognised by the sensors.

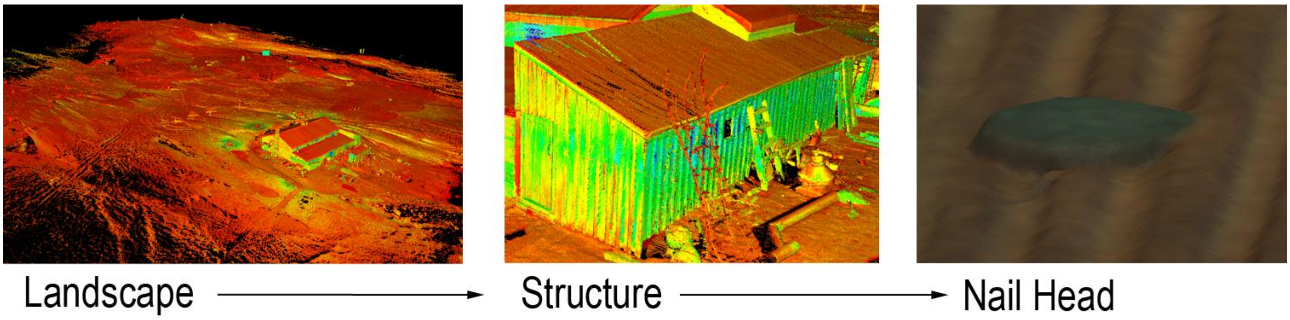

Figure 8: Representation of different scales and spatial resolution of survey data.

8. CONCLUSIONS

The ability of scanning technology to operate in the Antarctic has presented new opportunities for the recording and analysis of weathering and conservation of historic structures. Baseline as-built data onto which future surveys can be added will aid the future spatio-temporal modeling of biological and non-biological deterioration of the huts. A second survey season is planned for January 2012, where we will endeavour to finish the interior scans on Terra Nova and Discovery huts and undertake more scanning and modeling of ablated surfaces and soft rot areas at all three huts. A new site at Cape Crozier will be visited and a new hut and stone igloo remnants, the site where Wilson, Apsley-Garrard and Bowers withstood a cyclone in "The Worst Journey in the World", will be recorded.

Future work will involve modeling data for the K021 team, establishing a digital 3D inventory for the huts and artefacts and creating 3D models for education and tourism purposes.

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