





Assembling Situated Knowledges In Contemporary Archaeology: Three-Dimensional Imaging in the Cherish Project

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Abstract

This thesis addresses the need within geographical scholarship — and the social sciences, more broadly — for new conceptual tools to better understand digital mediations of heritage. In particular, it considers the epistemic and ontological consequences of translating the "archaeological record"—i.e., the "material" components of human history — into digital contexts. Geo-spatial visualising technologies are being used more and more extensively within contemporary archaeology and heritage sciences. With increasing frequency, archaeologists are using methods like drone-based photogrammetry (UAV survey), laser scanning, LiDAR, and more to develop new methods for research as well as public-facing historical reconstructions. Often these methods resolve in robust digital visual "objects" ranging from 3D models to digital elevation maps (DEMs), which can serve to illustrate findings or hypotheses, to assist in morphological analyses, or as tools for interpretive learning. These outputs are filling up screens across classrooms, lecture halls, galleries, and museums alike. In many respects they are changing how archaeological knowledges are now produced, circulated, and articulated.

As digital heritage visualisations increasingly come to function as surrogates for threatened heritage sites and objects, efforts to critically theorise the production and/or use of such objects — particularly as it pertains to the types of knowledges they carry — remain underdeveloped. This thesis contends that digitally visualised archaeological knowledges must be understood not only as socio-material constructs, but as emergent through both the socio-technical assemblages inherent to their production *and* the situated material engagements practitioners perform in order to render them.

The thesis takes as its case study the Cherish Project: a collaborative EU-funded research initiative designed to monitor the impacts of climate change on coastal heritage sites in both Ireland and Wales. It is particularly centred on the project's stated aim of delivering a comprehensive baseline of 3D data for the continued management of eroding heritage landscapes. Utilising theoretical concepts derived from literatures on *assemblage theory*, *situated knowledges*, *agential realism*, and *the ontologies of digital objects* this thesis performs a detailed analysis of three of the Cherish project's prescribed methodological workflows; namely, UAV survey, laser scanning, and analytic walkover earthwork survey. It traces the production of Cherish data from their initial acquisition, subsequent processing in secondary stages of post-production, and eventual cohesion as digital objects with prescribed uses. In so doing it reveals the production of digital heritage visualisations — and the knowledges they ultimately carry — as being crucially defined and shaped by the spatial, relational, and situated configuration of the components assembled in their production.

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Chapter 1: Introduction

1.1 Prelude

It had been getting down to the wire. After four days of rainouts and windstorms we were finally going to be able to get the drone up and do some photogrammetry. As the ardent and curious PhD student, my experience in County Kerry up to this point had largely been defined by assuring my hosts that—irrespective of the foul weather—I was still getting valuable data. Today, however, was different. The mood around the breakfast table was lifted. Everyone compulsively checked weather and surf report apps on their phones to confirm what was already evident looking out the hotel window: the conditions were finally right. Since arriving from Dublin, we had made several short visits to numerous eroding archaeological features and landscapes dotted along Kerry's dramatic and craggy coastline. All in preparation for this very break. And so, after loading the car with all the necessary kit, we set off again, feeling prepared and eager.

I had been travelling with two field archaeologists and the senior geo-surveyor from the Discovery Programme, an Irish research institution centred on technology and innovation in archaeology. The Discovery Programme is also one of four core partners in the Cherish Project, an EU-funded research initiative designed to monitor the impacts of climate change on coastal heritage sites in Ireland and Wales through digital visualisation methods and technologies[1]. The Kerry coastline comprises one of the five zones Discovery has targeted as designated research areas for their Cherish initiatives. Within this geographical zone Discovery has further selected nine individual sites for repeated monitoring and visualisation (*figure 1.1*). These archaeological sites range from monumental structures, to shipwrecks, to anthropogenic earthworks. On this particular morning we were heading back to Dunbeg

[1] It should also be noted here that while the work of the Cherish Project is contextually grounded in concerns about climate change, such framing holds little consequence for the enactment of the procedures observed for *this* study. Put another way, the enactment of the procedures here observed would likely be the same in any number of contexts. As such, the climate-based context of Cherish here serves secondary, though no less important role; namely, the degree to which it underscores both the value and diversity of applications such methods hold within archaeology and beyond.

Fort; a remarkably well preserved — and heretofore heavily touristed — Iron Age promontory fort, complete with a striking stone roundhouse and a quickly advancing eroding cliff face (*figure 1.2*). To date, Dunbeg has functioned as something of a flagship site for Discovery's contributions to Cherish. It is not only a well-known and regionally celebrated heritage destination; it has also endured remarkable collapse since the Cherish project began in 2016. In the winter of 2017/2018, for example, Dunbeg ceded some 3,000 cubic metres of earth to the sea overnight (Drohan, 2018; Pollack, 2018; Robinson, 2018). It is this very volatility that makes it an ideal proof-of-concept test site for Cherish. Three years into the five allocated for the project and Dunbeg has been both surveyed and modelled more than any other site within the Discovery Programme's remit.

Gliding along the crooked, winding roads that led from our hotel to Dunbeg Fort, I combed through the notes I had already produced since arriving in Ireland. Hamstrung by the unpredictable April weather, we had spent the last four days conducting site reconnaissance, testing a newly acquired submarine drone, securing permissions to survey from local landowners, and producing "plane table drawings". Basically, everything beside drone survey and/or laser scanning that the inclement weather would permit us to do. Reading through them, I was struck by the irony of the fact that the very tools best suited to monitor the climate-induced erosion of heritage landscapes were rendered unusable by even the lightest of rains or gust of wind over 23km/hour. Beyond that, however, my notes also revealed considerable detail about the multifaceted components inherent to — yet not immediately obvious within — the photogrammetry we were finally on our way to enact. Its foundations in geospatial measurement, for example, or its dense relationships to the other field methods gathered under the Cherish scheme. The visualisations this survey would ultimately produce, I knew, could be purposed towards a number of dynamic applications. I'd seen them — and models like them — circulating on Twitter for several years, providing users



Figure 1.1. *Map and photographs detailing both a cartographic overview of sites the Discovery Programme's investigation sites in Co. Kerry, as well as two images of such sites. The red dots on the map signify the locations Cherish had identified at the outset of the project. Since 2016, however, new sites have been added within each of the original five "case study areas". Source: graphic taken from a PowerPoint presentation drafted by Anthony Corns and Robert Shaw of the Discovery Programme in 2018.*

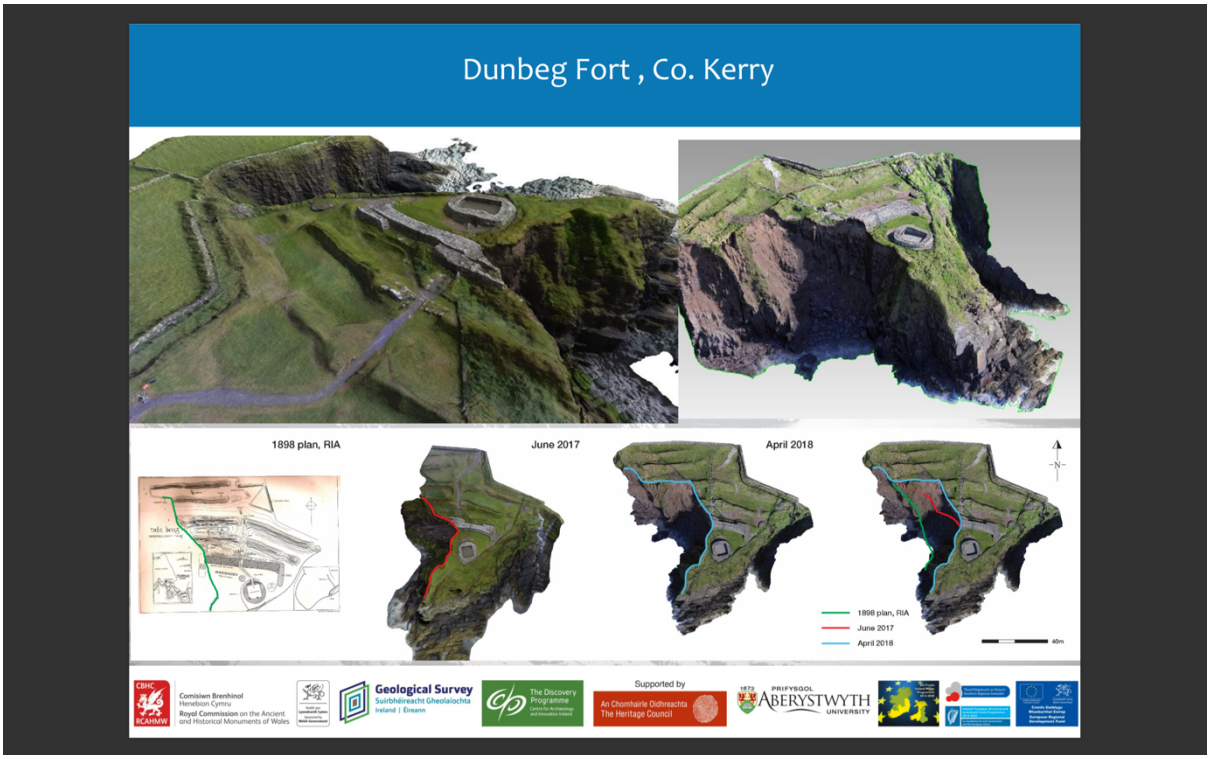


Figure 1.2. *Detail of Dunbeg Fort — derived from 3D models produced through photogrammetry — comparing its recent land loss to existing site records. Using a plan drawing dating from 1898, the above graphic contrasts two recent surveys taken in 2017 and 2018 with the existing historical record. The erosion of the cliff face is here illustrated with green, red, and blue boundaries, each denoting the location of the cliff face at respective dates. By the end of my field work I had observed the rendering of a 3rd UAV survey, though it has yet to factor into similar analysis or illustration. Source: graphic taken from a PowerPoint presentation drafted by Anthony Corns and Robert Shaw of the Discovery Programme in 2018.*

with an approximation of engagement with heritage sites or monuments that had already dramatically changed. I'd also seen photogrammetric models used to perform impressive volumetric and/or geomorphological analyses in the context of lectures and conferences. These visualisations — these "digital objects" — could articulate a diverse array of knowledges, which were already finding tremendous use in the contexts of research and outreach. Yet the constitution of these knowledges — the epistemic consequences of engaging with and documenting built heritage through digital visualisation — was then, and still remains, somewhat opaque. There was pronounced gap between what I perceived as a collective understanding of a method like photogrammetry as a ready-to-hand tool for archaeological investigation and an understanding of the knowledge-carrying digital objects such methods can produce. As such, I had arrived in Ireland intending to forensically trace the production of these visualisations, to follow the data from its initial derivation in the field and on through to its final articulations as 3D models. Rumbling towards to Dunbeg along the "Wild Atlantic Way", I already had a vague and theoretical notion of how photogrammetry worked. Today, however, I would finally get to observe one of the many ways in which the Cherish Project translates heritage sites into vivid three-dimensional visualisations.

1.2 Research Questions

This thesis interrogates how archaeological research methods like photogrammetry translate heritage sites and monuments into digital objects. It is primarily centred on my observation of the digitisation methods the Cherish Project uses to model and analyse Welsh and Irish coastal heritage sites threatened by erosion. Following the production of survey data from its initial acquisition in the field to its eventual visualisation as models with distinct applications, this thesis follows the mobility of these datasets as an ethnographic method through which the complex and multi-sited nature of this work can be traced.

The path that had led me to this research was a circuitous one. I had first encountered 3D renderings of heritage sites and artefacts while researching the intentional destruction of both during the civil wars of Iraq and Syria as a master's student. I became increasingly interested in the use of digital visualisation methods in relation to the conservation or reconstruction of these threatened sites, spaces, and objects. The outputs of these efforts were not only producing models capable of carrying considerable emotional or affective heft, but were being produced within parameters of remarkable accuracy, often geo-referenced to the centimetre. Put another way, they could function as both objects of memorialisation and advocacy, as well as technical objects of scientific investigation.

The more my research developed, the more the proliferation of digital heritage objects seemed to spool out in a variety of directions. Screens across classrooms, lecture theatres, galleries, and museums are filling up with these objects, with applications ranging from platforms for collaborative research to showcases for historical reconstruction (Baik, 2017; Benko et al, 2004; Berggren et al., 2015; Chevrier et al., 2010; Chiabrando et al., 2018; Corns et al., 2015; Corns et al., 2017; Corns and Shaw, 2009; Corns and Kennedy, 2015; Fish et al., 2017; Forte et al., 2012; Forte, 2014; Forte, 2011; Forte and Kurillo, 2010; Forte and Pietroni, 2009; Herráez, et al., 2012; Hervy et al., 2009; Maícas et al., 2017; Molloy et al., 2016; Morgan, 2009; Ortiz-Cordero and Hidalgo Fernández, 2017; Pescarin et al., 2008; Sacher et al., 2015; Scopigno et al., 2017; Shaw, 2017; Vincent et al., 2015). These digital heritage objects and their various applications alternately serve to illustrate findings or hypotheses, to assist in morphological analysis, or as tools of interpretive learning.

Despite their growing pervasiveness, however, it is the contention of this thesis that digital heritage objects remain under-theorised and, in many respects, misunderstood. As with other visualisation practices across the sciences more broadly, digital heritage objects are often assumed to "show exactly 'the things themselves as they appear'", where

"landscapes, lifeways, human and non-human entities are portrayed as static, timeless, uncomplicated, or easily knowable" (Vertisi, 2015, pg. 8; Perry, 2009, pg. 392; Perry and Beal, 2015). Much of this is compounded because these heritage objects are *digital* visualisations derived from *data*. Across many disciplines, data is still problematically discussed as being either neutral or objective. Following Rob Kitchin, however, this thesis contends that data "do not exist independently of the ideas, instruments, practices, context, and knowledges used to generate, process, and analyse them" (Kitchen, 2014b, pg. 2). As such, both the digital heritage objects this thesis concerns — as well as the data from which they are derived — are here discussed as condensations of site-specific (or *situated*) material engagements between the practitioners that produce them, the technical instruments and softwares employed in these practices, and the heritage sites/features upon which they are based. They are further defined by their mobility and distribution, both in the context of how they are initially produced and how they are circulated and used once formalised. Digital heritage objects — such as those produced by the Cherish Project — often function as surrogates for threatened heritage sites and objects that are either disappearing or have already disappeared[2]. In most cases they are circulated and showcased as works of preservation and conservation. They are utilised to broaden access to cultural heritage sites and resources that have grown precarious and delicate. As our collective relationships to heritage become increasingly digitally mediated, then, it is imperative we come to understand these objects better. This thesis begins with the contention that, in order to understand digital mediations of heritage, we must both address their respective means of production as well as their unique status as digital objects. Grounded in a more general understanding of heritage resources as active, dynamic, and socio-material systems (rather than static systems), this

[2] After the destruction of Palmyra, for example, much was made over the travelling replica produced by the Institute for Digital Archaeology (Brown, 2016). Furthermore, models of Cherish sites like Dunbeg Fort, for example, are based on surveys of the site that have since eroded dramatically.

thesis further explores how digital heritage practices are both changing and enriching our relationships to heritage sites and objects more broadly (Desilvey and Edensor, 2013; Desilvey, 2017).

As such, this research asks:

— *How do the knowledges carried by digital heritage visualisations come to be constituted?*

This core question is in turn broken down into three further questions.

— *How are digital heritage data initially produced at field sites, and what are the consequences of the site- and project-specific methods enacted to produce such them?*

— *How do digital heritage data change as they move between sites?*

— *How do digital heritage data cohere into digital objects?*

The above three questions have specifically guided the organisation and flow of the empirical chapters (chapters 4-6). Yet while each question — from a purely structural standpoint — helpfully corresponds to the specific activities observed in the field, when considered in concert they combine to illuminate something far more interesting; namely, that by tracing their production from acquisition to application, digital heritage objects — and the knowledges they likewise carry — are revealed as being inherently situated, multi-sited, and iteratively assembled. As a result, this thesis produces an understanding of digital heritage objects grounded in discussions of ontological multiplicity. What this research further discloses, then, is just how densely entangled each iterative stage of development and translation inherent to heritage data is with how these objects should and can be understood.

1.3 The case study: The Cherish Project[3]

I considered and approached many different groups and organisations when I began exploring potential case studies for my research. Not only are digital visualisation methodologies being used rather broadly across the heritage sciences, but each practice is built around different toolkits for visualisation. As a master's student, for example, I had interfaced with practitioners from Global Digital Heritage[4], the British Museum[5], Iconem[6], and ThinkSee3D[7]. As research initiatives producing outputs ranging from 3D models of monumental structures to the 3D printing of museum artefacts based on laser scans and photogrammetry, each would have provided a unique opportunity to observe the digitisation of heritage sites or objects, albeit within somewhat limited scopes. I was looking for an active and prolific research initiative centred on *multiple* approaches to digital visualisation. The ideal case study would encompass a range of both sites/objects being digitised, as well as methodologies being pursued. The attendant fieldwork, I felt, needed to capture different articulations of methods in a diverse array of contexts. Furthermore, because this research targets the unique and site-specific configuration of tools and expertise within a given process or method, such a case study would be centred on multiple practitioners with differing areas of specialisation. Somewhat serendipitously, I was lucky enough to contact the Cherish Project early into their 5-year charter.

My route to selecting the Cherish Project as my core case study was funnelled through my primary interest in the Discovery Programme. I had found the Discovery Programme through their profile on Sketchfab.com, a browser-based platform that operates much like a YouTube for 3D modellers (replete with a well organised 'cultural heritage' sub-

[3] For an exhaustive description of the Cherish Project, as detailed in its original funding charter/executive summary, see Appendix I.
[4] https://globaldigitalheritage.org/
[5] https://github.com/BritishMuseumDH
[6] https://iconem.com/en/
[7] https://www.thinksee3d.com/

platform). Discovery has a robust Sketchfab profile, with models of archaeological objects and features ranging from cabinet-sized museum objects[8], to 1.5m high Ogham stones[9], to monumental structures and landscapes[10]. I reached out to Discovery in September 2018 to inquire about their forthcoming projects and quickly developed a correspondence with Anthony Corns[11], their chief technology officer. Anthony was receptive to my project proposal, even demonstrating a familiarity with some of its core theoretical concepts. It was his suggestion that I develop my case studies not only around Discovery's involvement in the Cherish Project, but around the work being undertaken by their partners in Wales. He contended that Cherish — by virtue of its scale, scope, and duration — would provide ample opportunity for observing and following a number of digital visualisation methods all grouped together under the banner of a holistic research context.

Funded through the European Union's *"Ireland and Wales Co-Operation Programme (2014-2020)"* to the sum of roughly four million euros, the Cherish Project is composed of four core partners:

— The Discovery Programme
— The Royal Commission on Ancient and Historical Monuments of Wales (RCAHMW)
— The Geological Survey Ireland (GSI)
— Department of Geography and Environmental Sciences, University of Aberystwyth

Where the GSI and the University of Aberystwyth produce geological profiles of study areas in both contemporary and paleo-environmental contexts (respectively), the Discovery Programme and the RCAHMW participate in capacities designed to mirror and complement each other. Both groups focus directly on the digitisation, visualisation, and monitoring of key sites and features, centred on a methodological scheme that runs from prospection to

[8] https://skfb.ly/666pI
[9] https://skfb.ly/ZUHJ
[10] https://skfb.ly/6yOpQ
[11] The names of all respondents are used here with their written consent.

analysis. As it concerns the core deliverables of the project (*see appendix I for an in-depth description of all Cherish initiatives*), Discovery and the RCAHMW are principally concerned with developing guidance/protocol for future survey, the production of a 3D baseline dataset of selected heritage assets comprising a robust and open access "data legacy".

The Discovery Programme and RCAHMW pursue these initiatives via a refined set of prescribed survey methodologies ranging from aerial photography to remote sensing techniques such as photogrammetry and laser scanning (*figure 1.3*). From this methodological toolset, my fieldwork principally concerned the use of UAV-survey (also referred to as drone survey), laser scanning, and analytic walkover earthwork survey[12]. The reason this research is primarily structured around the three methods mentioned above is that these are the methods Cherish repeats on site throughout the duration of their project. I observed the enactment of these methods at selected coastal sites in both Ireland and Wales[13], as well as their subsequent processing at either group's headquarters/home offices (*figure 1.4*). From a design standpoint, then, this research traces the active production of digital heritage datasets and objects from their principal "*acquisition*" in the field, through their iterative cohesion as digital objects, to their eventual application as tools for analysis, management, and illustration.

While Cherish employs numerous individuals across the four assembled partners (in capacities ranging from administrative to field-based), I chose respondents based on their specific involvement in the methodologies I planned to observe. At the conclusion of my field work, I had worked intimately with a total of eight Cherish investigators[14]. These included two field archaeologists, the lead geo-surveyor, an office-based 3D modeller, and

[12] For an in-depth description of these techniques, see the "Justification of Methods" (Chapter 3).
[13] For an exhaustive description of Cherish study areas, see Appendix I.
[14] For exhaustive profiles of these respondents, see the "Justification of Methods" (Chapter 3).

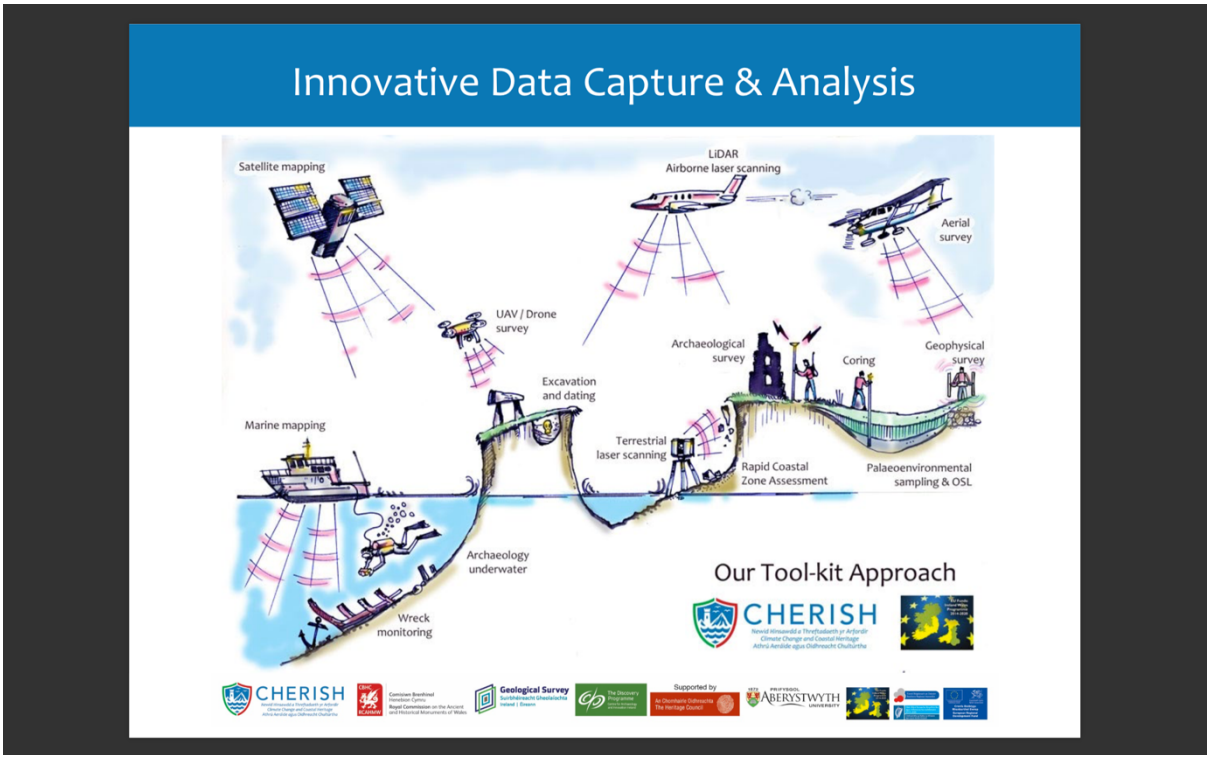


Figure 1.3. *A graphic overview of the numerous methods Cherish has chosen in pursuit of its outlined research initiatives. Of the methods detailed in this illustration, this thesis primarily concerns UAV/Drone survey, Terrestrial laser scanning, and Archaeological survey (also known as analytic walkover earthwork survey or GNSS survey). While in the field I also observed methods of excavation and dating and wreck monitoring. Furthermore, there was often discussion centred on either geophysical survey or aerial survey. As will be revealed throughout this thesis, all of these chosen methods are complementary and many — if not all — are often performed on the same sites at iterative stages. Source: a graphic taken from the original Cherish Charter, 2016.*

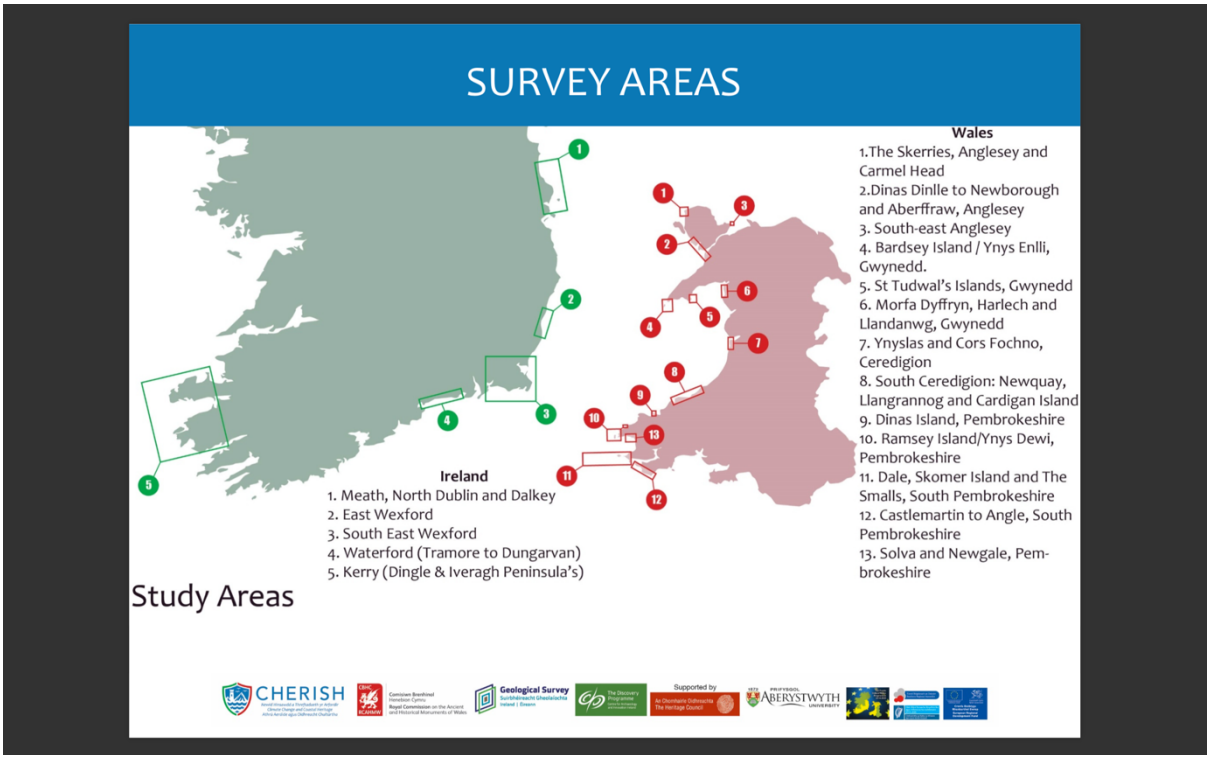


Figure 1.4. *A cartographic overview of the selected areas of study alternately taken up by Irish and Welsh Cherish partners. For this thesis, I travelled to and observed survey at Irish sites in study area 5 and Welsh sites in study areas 2, 7, 12, 13. These locations were not chosen for any specific reasons beyond the fact that these were the locations flagged for survey at the time of my visits. Source: a graphic taken PowerPoint presentation drafted by Anthony Corns and Robert Shaw of the Discovery Programme in 2018.*

Cherish Project lead from Discovery, as well as an aerial photographer, field archaeologist, and principle Cherish investigator from the RCAHMW. Working with the Cherish Project provided the novel opportunity to travel with these practitioners as well as with the data they produced as they moved between sites of production. Furthermore, as a practice structured around the repeated monitoring of the same sites intermittently over the course of their charter, I was able to conduct meaningful analysis of separate surveys and visualisations produced of the same sites, by the same teams, using the same equipment. Finally, because the Cherish Project (once concluded) will resolve in an open-source data repository, I was permitted a level of access to Cherish data I was unlikely to find elsewhere. As a case study, the Cherish Project was dynamic and accessible enough to accommodate both the initial goals of my project as well as the unanticipated directions it would grow in as our collaboration developed.

1.4 The Thesis Structure

The primary aim of this research is to understand the relationship between *how* digital-visual archaeological projects are enacted as well as the types of knowledges that are produced as a result. Travelling between Ireland and Wales — between the offices and field sites of my chosen respondents — I came to further understand the processes I was observing as being inherently multi-sited. As a result, I've organised these "sites" around three concepts:

— "Acquisition", meaning the initial derivation of visual and spatial data necessary to produce specific visual products.

— "Processing and visualisation", i.e., the means through which "acquired" data is initially assembled and "translated" into geo-referenced geometric objects and surfaces.

— "Coherence", or the processes and stages at which the organisation and rendering of a given project's dataset produced what can identified as digital heritage objects.

As alluded to above, it is through this nexus of identified 'sites' and the research questions of the thesis that my empirical chapters have been structured. In addition to these chapters, the thesis is further framed by a chapter on theoretical orientations and a chapter on my methodological approaches to fieldwork.

The chapter, *Theoretical Orientations*, contrasts discussions of *assemblage theory, situated knowledges, agential realism,* and *the ontologies of digital objects*. In so doing it develops the theoretical means for addressing the mobility and distribution of digital heritage data, the various ways in which sites of production are assembled, and what it means to say that the enactment of such work is inherently *situated*. The third chapter, *An Overview of Methods*, details how I chose to both explore my theoretical orientations empirically and most effectively embed myself in the field. This chapter not only addresses how I employed semi-structured interviews, on-site participant observation, and visual methods in relation to the Cherish Project, but the challenges and consequences of doing so. The first empirical chapter, *Sites of Acquisition*, concerns how Cherish practitioners derive the survey data that eventually becomes visualised as models at later stages. This chapter not only addresses the degree to which sites of acquisition are *assembled*, but also the numerous and procedural means through which the enactment of data acquisition *spatialises* targeted heritage sites. The second empirical chapter, *Sites of Processing and Visualisation,* addresses the translation of acquired data as they move from the field to the office. Following the iterative development of acquired data as it is reconfigured and situated in new digital contexts, this chapter describes how activities at this stage are both contingent upon, and critically differentiated from, the assembled and performed acquisition of data in the field. The final empirical chapter, *Digital Heritage Objects*, asks when and where Cherish data coheres as digital objects. In specifically attending to factors such as the organisational agency of the Cherish database, for example, or the interfaces ultimately used to visualise and circulate Cherish

work, this chapter develops concepts of digital objectivity around discussions of ontological multiplicity.

1.5 Conclusion

Two months after the trip to Dunbeg Fort, I would return to Dublin to observe the processing of the data we had collected on that rare still and sunny day in early April. As hundreds of photos and coordinates gradually cohered into 3D digital object resembling the eroding headland, it occurred to me that it was third such model of Dunbeg I'd seen rendered since beginning my project. I realised not only that the Cherish Project, its methods, and its outputs were changing as the headland changed, but that the dynamism of the project overall was inextricably tied to the mobility and mutability of the data it produced, as well as to the dynamism of the physical landscape. Having travelled to sites elsewhere in Ireland with Discovery, and throughout the Welsh coastline with the RCAHMW, this was an observation I would experience several times over throughout my time in the field. Digital heritage practices such as those employed by the Cherish Project are changing how these sites can be seen, engaged with, and understood. This research will explain how.

Chapter 2: Theoretical Orientations

2.1 Introduction: "This Sounds Rather Latourian..."

It did not take long for me to make contact with Anthony Corns, the technology officer and lead Cherish Project investigator for the Discovery Programme. I had been circling the Discovery Programme as a potential case study for weeks in the summer of 2018, and — after sending a brief letter of introduction — had been contacted directly by Anthony shortly after. We arranged to speak over Skype so I could provide a more elaborate explanation of both my project and my budding interest in the work he and his team did at Discovery. I started with the broad strokes: my project was about knowledge production and digital visualisation in the heritage sciences, I'd written a master's dissertation on similar topics, and I had interfaced with several research entities similar to Discovery during my MA. Furthermore, I explained that what I had hoped to do with my research was to forensically trace the production of digital heritage objects from survey to application. I used the conversation as an opportunity to rehearse my learned familiarity with some of the methodological approaches I knew the Discovery Programme employed. In particular, I outlined how I imagined any potential collaboration between Anthony and myself could be organised around what I already understood about the photogrammetric modelling of monumental heritage sites. I was deliberately careful to keep my explanations from drifting into the theoretical discussions I'd been developing over the first year of my DPhil studies. For the most part I stuck to what I understood about pertinent technologies and methods. When I had finished my pitch, however, Anthony responded in a way that surprised me. Pondering my proposal, Anthony's first was remark was that he thought the project sounded "rather *Latourian*" and asked whether the field work I was imagining was structured around Actor Network Theory.

It was an astute observation that anticipated how — at the time of our conversation — I was already developing the theoretical questions and focuses of my research. Latour's essay

Circulating Reference (1999), in particular, was both a formative and instructive text I had consulted earlier in my first year as a DPhil candidate. As an ethnography of soil scientists working at the fringes of the Brazilian Amazon, *Circulating References* details the intricate and multi-sited means through which the observed activity undertaken by scientists in the field comes to be iteratively distilled into abstracted knowledges, journal articles, and graphic figures. Challenging deeply entrenched suppositions about the distance separating the ontological domains of "the world" and "words", Latour contends that "there is neither correspondence, nor gaps, nor even two distinct ontological domains" (Latour, 1999, pg. 24). As a result, the essay demonstrates how the translations of soil to data, data to experiment, and experiment to publication are facilitated through intricate and (most importantly) cohesive networks of reference and signification.

One of the essay's concepts I have found particularly instructive is how Latour describes the relationship between laboratory sites and field sites, and particularly the extent to which they are described as permeating one another and reconstituting themselves in different physical locations. Beginning with the contention that "...scientists master the world, but only if their world comes to them in the form of two-dimensional, superposable, combinable inscriptions", Latour focuses early on how discrete portions of the forest and surrounding savannah are segmented by his respondents into gridded and manageable allotments (Latour, 1999, pg. 29). In so doing, these scientists effectively reassemble the field as a laboratory, a move which enables not only the regulated derivation of data, but further ensures such data can be commutable to new sites and contexts. In following this process of extraction and abstraction — particularly as samples journey from the "field" to the "lab" — Latour further questions the extent to which aspects of "the field" come to be reassembled in spaces of scientific experiment and analysis:

> So are we, therefore, far from the forest? Let us say we are in-between, possessing all of it through these delegates, as if congress held the entire United States; a very economical metonymy in science as in politics, by which a tiny part allows the grasping of the immense whole (Latour, 1999, pg. 36)

The fluid correspondences Latour traces between field sites and laboratories resonate rather profoundly when applied to the case studies this thesis targets, as does the degree to which such transpositions are portrayed as being facilitated through methods of site-specific spatial organisation. The digitisation of heritage landscapes and monuments is likewise facilitated through the processual assembling of distinct frameworks of reference across numerous sites of production. The following empirical chapters not only detail the various means through which practitioners *spatialise* heritage sites through acts of measurement and observation, but how the spatial registers produced through such practice travel between sites of production. A large part of what the empirical chapters demonstrate is how the translation of spatial registers derived in the field into contexts of digital processing is both primary and foundational to how physical heritage landscapes eventually become visualised and cohesive as digital objects. As such, how this thesis describes and discusses the iterative *translations* of heritage data has also been influenced, in part, by *Circulating Reference*. For Latour, it is the very act of these referential translations and transformations that effectively counters any supposed ontological distance separating the domains of nature and language:

> ...it seems that reference is not simply the act of pointing or a way of keeping, on the outside, some material guarantee for the truth of a statement; rather it is our way of keeping something constant through a series of transformations. Knowledge does not reflect a real external world that it resembles via mimesis, but rather a real interior world, the coherence and continuity of which it helps to ensure (Latour, 1999, pg. 58).

In the project of tracing the assembling of knowledges carried by digital heritage objects, then, *Circulating Reference* provides a means to link digital heritage outputs with both the physical landscapes from which they were derived, and the procedural material engagements performed by practitioners during their production.

Latour's text *Reassembling the Social* (2007) also proved instructive in addressing questions about how best to conceptualise the "social" constitution of the research entities I targeted, as well as the degree to which their activities, methods, and outputs might be discussed in terms of "social constructivism". For Latour, not only does too much of the academy's broad use of the term "social" lack nuance, but too often scholars seek out and emphasise 'social constructivism' without considering just how problematic and taken-for-granted discussions of 'the social' can be. As a result, Latour contends not only that relations, events, and active interchanges (rather than abstract structural concepts) are the things which make "the social" perceptible to researchers, but that entirely new topologies of social entities can be traced by following these interchanges and connections:

> But it does not require much effort to see that a virtual and always present entity is exactly the opposite of what is needed for the collective to be assembled: if it is already there, the practical means to *compose* it are no longer traceable; if its total, the practical means to totalise it are no longer visible; if it is virtual, the practical means to *realise, visualise,* and *collect* it have disappeared from view (Latour, 2007, pg. 163).

Read together with *Circulating Reference,* Latour's notions of both "the social" *and* knowledge production share a distinct and productive overlap in how both reject the assumed "distance" between the domains of abstraction and observed phenomena. In implementing these notions in my own research, both texts influenced how I have come to conceptualise the knowledges associated with digital heritage visualisations. Put simply, to frame them within the language of social construction alone is to ignore the numerous non-human, material, and technical components inherent to the production of digital heritage objects. As such, the "construction" of knowledges this concerns will instead be described in terms of socio-materiality. Furthermore, it is in targeting distinct moments of interchange between practitioners, their tools, their methods, and the features they survey that the assemblages they collectively comprise come into focus.

Where *Circulating Reference* asks how scientists "put the world into words", this thesis asks how archaeologists translate heritage landscapes into digital visualisations. To approach this question theoretically, however, requires more than Latour. For one, the practices of digital visualisation this thesis targets are complicated by both the mutability of the data they produce as well as the iterative and site-specific conditions that define individual projects and processes. As such, the systems of circulating reference inherent to the derivation of digital heritage objects are defined by aspects of modularity, multiplicity, and mutability, all of which factor into the empirical work of this research. To these ends, this literature review is initially centred on discussions of *assemblage theory,* specifically assemblage thinking's capacity to conceptualise knowledge-producing practices composed of mutable heterogenous components. The chapter discusses theories of *assemblage* as a means to address the iterative fitting together of the various components inherent to the activities and processes observed. From the different strands of assemblage thinking it consults, this chapter specifically teases out key discourses on how the constitution and co-functioning of given assemblages — regardless of mutability of their respective configurations — result in the emergence of specific properties, knowledges, and digital visual outputs.

This literature review is further oriented around theories of *situated knowledges* and *agential realism*. In *situated knowledges* it locates the means to address the positionality and mediated orientations that define the relationships heritage practitioners have to both methodologies pursued and the data/visualisations produced. In *agential realism* the chapter identifies the means to crucially link the enactment of scientific observation or measurement to both the phenomena being observed and the knowledges abstracted. Finally, key literatures concerning *the ontologies of digital objects* are further consulted in order to better understand the 3D models produced through these practices.

2.2 Assemblage theory: the configurations of assembled components

As a research project situated between geography, archaeology, and heritage sciences, assemblage thinking has proved a helpful conceptual through-line between the disciplines this thesis addresses. The notion of assemblage was first elaborated at length by Deleuze and Guattari and has since been reworked by social scientists across numerous disciplines towards a number of different research objectives. As a concept, assemblage usefully provides a means to theorise how a heterogenous collection of social, material, and technical agents not only can cohere as a co-functioning entity, but how such ensembles come to be productive of emergent things and properties through their collective co-functioning. This section will clarify the thesis's use of the term assemblage to emphasise its applicability to the case studies this research targets.

To discuss theories of assemblage as they specifically relate to methods of archaeological investigation, however, first requires something of a disclaimer; namely, that the notion of assemblage has an entrenched meaning within archaeology that spans decades of scholarship (Hamilakis and Jones, 2016; Harris, 2017; Needham, 2017). Traditionally employed to address the material relationality of artefacts within both spatial and temporal contexts, archaeological assemblages—particularly in the context of field-finds and excavations—commonly describe the "aggregation of diverse objects united by a distinctive and clearly defined context of variable scale" (Hamilakis and Jones, 2016, pg. 77). This could pertain, for example, to the correspondence between a discrete collection of artefacts and an already-established archaeological record for a surrounding geographical region.

However, in specific sectors of contemporary archaeology—namely "post-processual", "behavioural", or "reflexive" archaeologies—notions of assemblage have evolved to broaden their consideration of the material relationships of finds or artefacts from

an understanding of the "autonomous and tacit physicality of things" to one which acknowledges or considers something of the "symmetrical role of things in their relationships with people" (Lucas, 2012, pg. 162). As such, archaeological discussions of assemblage have begun to acknowledge a more diverse range of participants, social entities, or components, which demand a reframing of both the typological similarities and temporal boundaries that had traditionally defined them (Harris, 2017). And it is here—in the development of the term towards a more nuanced account of the heterogeneity inherent to the production of archaeological knowledges—that archaeological discussions of assemblage come to resonate with discussions of the same across other disciplines.

Geographers, by contrast, have used both assemblage thinking *and* explicit discussion of the digital to address socio-spatial/social material configurations defined by both mutability and mobility (Anderson et al, 2012; Featherstone, 2011; Greenhough, 2011; Greenhough, 2012; Hallot et al., 2016; Legg, 2011; Ong and Collier, 2005; Pickren; 2018). Research in digital geographies, for example, has long discussed the correspondence between digital technologies and the social entities within which they are embedded as being mutually generative and impactful upon how either should be studied or understood (Crang, et al., 2006; Crang, 2015; Klinkenberg, 2007; Lammes, 2017; Wilmott, 2017; Zook and Graham, 2007). Furthermore, by foregrounding *process* as the organisational principle of the socio-material/socio-spatial, geographical articulations of assemblage thinking enable us to "think outside a distinction between the structured and the unstructured" without necessitating a priori constructs like scales, place, territory, or networks (Anderson et al, 2012, pg. 175). Doing so proves particularly helpful in addressing both the spatial distribution of the assemblages this thesis considers, as well as the mobility of the components it locates in such assemblages. Specifically, as it relates to how this research uses *circulating reference,* thinking geographical articulations of assemblage theory together with both Latour and

assemblage thinkers from other disciplines further enables us to address the abstraction and production of heritage data and knowledges in mutually generative terms (DeSilvey, 2017).

To illustrate and contextualise how assemblage thinking broadly applies to the case studies this thesis considers, let's conduct a thought experiment. Let's hypothetically enumerate the assembled components necessary to enact a basic photogrammetric drone survey and how, roughly, they are distributed across numerous sites[15] . To begin with, there is the landscape or monumental feature being digitised. In order to perform the initial derivation of digital images from this hypothetical feature one would — at the bare minimum — need the following:

— a drone (with corresponding control console)
— a tablet (for seeing through the drone, piloting the drone, and taking photographs)
— a mountable digital camera (complete with SD card for storing images)
— a surplus of charged batteries
— a GPS antenna (complete with SD card for storing coordinates)
— "control targets" for registering fixed locations visible from the drone
— a skilled practitioner with experience in registering locative measurements, experience in drone-based photography, familiarity with all the above equipment, and a license to pilot said drone.

Once the acquisition of primary data has been performed, the process then moves from the field to the office, where both the coordinate-based and visual datasets are transferred to sedentary workstations/desktop computers. Here, the data further travels between numerous software platforms. As such, the assembled components at these secondary sites of processing and visualisation typically require, but are not limited to, the following:

— a powerful desktop computer with necessary capacities for processing visual data (both the Discovery programme and RCAHMW use *Alienware* computers)
— a software for organising/formatting large photographic datasets (typically Adobe Bridge)
— a software for organising/formatting coordinate data (typically Microsoft Excel)
— a software for rendering coordinate data as cartographic reference materials (typically ArcMap)

[15] A similar experiment could be performed for any of the observed activities detailed in the empirical chapters to follow.

— a software for performing all the iterative steps of photogrammetry (typically Agisoft Photoscan pro)
— again, a skilled practitioner with familiarity and expertise in using such tools and softwares.

Depending on factors like the targeted outputs, resolution baselines, and/or the relative size of both the feature being modelled *and* the resulting model itself, further software or procedures might eventually enter the fold as well. Crucial, too — and something that will be illuminated in the empirical chapters to follow — is that the distinct configuration of these components directly corresponds not only to the data that composes the resulting visualisations, but how these visualisations can be used in applied research contexts. How, then, to conceptualise these assemblages further?

To start, let's begin with Manual DeLanda whose mutual interest in assemblage theory and computer science proves particularly useful for addressing the assemblages this thesis locates within digital heritage practices. As a Deleuze scholar, DeLanda often works to render many Deleuzian concepts — including those specifically associated with Deleuze's collaborative writings with Felix Guattari — more accessible to social scientists. As it specifically concerns the notion of "assemblage" as it is taken up in *A Thousand Plateaus* (2013) or *The Anti-Oedipus* (2013), DeLanda makes a concerted effort to distil the *many* definitions of assemblage Deleuze and Guattari posit into something succinct and serviceable. Simply put, because Deleuze and Guattari's many notions of assemblage are defined by context-specific contingencies, it becomes difficult to commute any single definition to considerations of socio-material or socio-technical entities across variable scales (DeLanda, 2016). DeLanda's theory of assemblage has been developed as a means to effectively understand the manifold and endlessly productive co-functioning that results from embracing an ontology defined by *difference* (DeLanda, 2013). Crucially, however, DeLanda

contends that the project of refining a theory of assemblage must emphatically move beyond any tendency to ground our understandings of the social in the terms of subjectivities.[16]

DeLanda places great emphasis on the exterior relationships and frictions that exist between the individual components that make up an assemblage, further contending that these relationships and interchanges are the means by which a given assemblage comes to both possess and be generative of the *properties, capacities,* and *tendencies* of emergence (DeLanda, 2011). All of this is further bound up in how DeLanda positions assemblage thinking as a means to check any impulse to either "micro-reduce" our understandings of co-functioning socio-material ensembles to individual parts or phenomenological subjects.

> The very first step in this task is to devise a means to block micro-reductionism, a step usually achieved by the concept of emergent properties, the properties of a whole caused by the interaction of its parts. If a social whole has novel properties that emerge from interactions between people, its reduction to a mere aggregate of many rational decision makers or many phenomenological experiences is effectively blocked (DeLanda, 2016, pg. 9).

Put differently, in targeting the frictions and interchanges generated from the collective exteriority of a given assemblage's component parts—and in typifying these generative interchanges as having distinct and empirically definable characteristics—one is capable of grasping or understanding an assemblage by virtue of what is produced through its respective co-functioning. This becomes particularly useful when applied to contexts or situations where a given assemblage travels and iteratively changes across multiple sites and contexts (such as the workflows detailed in Chapters 4 and 5). If, after DeLanda, we assess and define socio-material assemblages on the basis of what they produce *as well as* what they are comprised of, we become better equipped to discuss them in terms of their mutability, mobility, and multiplicity.

[16] Part of the reason this has been so appealing to cultural geographers—and digital geographers in particular—is the embedded implication that doing so enhances our theoretical capacity to flatten social ontologies and thereby extend them to include both technological or more-than-human components.

Just as the principle of emergence is here reconfigured in order to check the impulse to "micro-reduce" assemblages to the individuation and subjectivities of its component parts, DeLanda also posits "relations of exteriority" as means to prevent what he terms "totalising" reductions:

> Unlike wholes in which 'being part of the whole' is a defining characteristic of the parts, that is, wholes in which the parts cannot subsist interdependently of the relations they have with each other (relations of interiority), we need to conceive of emergent wholes in which the parts retain their autonomy, so that they can be detached from one whole and plugged into another one, entering into new interactions (DeLanda, 2016, pg. 10).

Taken in concert, the dual principles of *emergence* and *exteriority* aim to establish a conceptual baseline from which heterogenous socio-material assemblages can be theorised regardless of their respective capacities to cohere, change, or be distributed across multiple sites and contexts.

The appeal of the DeLandian assemblage theory for this thesis, then, is its distinct capacity to address heterogenous socio-technical wholes which change, evolve, and develop over time. Understood as assemblages, the case studies targeted by this thesis, for example, can be defined by their inherent modularity and mobility; i.e., either the interchangeable and continuously updating nature of the technological instruments employed *and/or* the individuated articulation of expertise as performed by different practitioners at different sites, yet under similar circumstances. Assemblage theory, as presented by DeLanda, enables us to conceptualise how the site-and case-specific performance of Cherish workflow methodologies can be collated towards achieving uniform research initiatives and goals (such as the production of digital visualisations within specific standards of accuracy and resolution). Furthermore, particularly as it pertains to the production of digital heritage objects more generally, accounting for the configurational *difference* inherent to the production of specific digital visualisations further enables us to assess what makes discrete

outputs comparable or unique. The empirical potential of DeLanda's assemblage thinking which thesis develops is further centred on two more components derived from Deleuze and Guattari; namely, the concepts of *territorialisation* and *coding*.

In one respect, *territorialisation* is taken up as it relates to the most common understanding of the term, namely spatial associations such as the boundaries or borders that commonly define nations, cities, neighbourhoods, or communities. In DeLanda's work, however, it also concerns "the degree to which an assemblage's component parts are drawn from a homogenous state, or the degree to which an assemblage homogenises its components" (DeLanda, 2016, pg. 22). Factors such as "habit" and "technology" are presented here as two key factors capable of maintaining or disrupting an assemblage's capacity to alternately hang together, fall apart, or change (DeLanda, 2016). The establishment and maintenance of routines or protocols, such as "the repetition of traditional rituals or systematic performance of regulated activities", are here posited as territorialising factors capable of both stabilising "the identity of organisations" and giving them "a way to reproduce themselves" (DeLanda, 2016, pg. 32). Technological influences, on the other hand, are here posited as having both disruptive and reconfigurational capacities to have either "de-territorialising effects on organisations" or enable a given assemblage to "break away from the limitations of spatial location" (DeLanda, 2016, pg. 32). Particularly as it concerns a given assemblage's capacity to be distributed and yet remain cohesive across multiple sites of activity, is seen here as being determined, in part, by the extent to which their socio-material components are respectively territorialised.

Coding, by comparison, refers "to the role played by the special expressive components in an assemblage in the fixing of the identity of the whole" (DeLanda, 2016, pg. 22). The most obvious of such considerations could likely be explicated through discussions of either language or genetics. In the context of this thesis's consideration of digital heritage

initiatives, however, DeLandian notions of *coding* are used to address the synchronisation and mobility of data types and file formats that enable the processual generation of digital heritage objects. The most obvious example of this is the pervasive registration of all survey data (visual or otherwise) in set geographical coordinate systems and map projections. Thinking through *coding* and *territorialisation* together produces a parametric logic that DeLanda illustrates by comparing a hypothetical assemblage to a control console with two knobs indicating the degree to which its constituent components are both coded and territorialised. If we consider these terms in concert with DeLanda's notions of emergence ─ i.e., if we also ground our understandings of assemblages in terms of what emerges as a result of their co-functioning ─ we derive a means to consider how factors like the habituation of methodological protocols or the synchronization of technologies/data-types co-constitute what ultimately emerges (such as digital heritage objects).

2.3 Situated Knowledges and Agential Realism

Much of what DeLanda's account of assemblages enables us to do is begin to develop holistic understandings of the workflows associated with the production of digital heritage objects. DeLanda's notions of emergence, exteriority, territorialisation, and coding provide the means to see how such assemblages can remain cohesive despite their distribution across multiple sites of activity and production. Taken together with Latour, then, assemblage theory also helps us to comprehend how systems of circulating reference both come to be configured and remain cohesive, regardless of the potential mobilities of the components that comprise them. What DeLanda does not provide, however, is the means to account for the fact that ─ in their distribution across field sites, labs, interfaces, etc. ─ these assemblages are also crucially centred on site-specific and context-based material engagements between practitioners, their tools, and their subjects of study. As such, regardless of how factors such as the habituation of protocols, for example, stabilise a given assemblage or enable it to reliably reproduce

itself, the *enactment* of such protocols is contingent upon unique situations and circumstances[17].To these ends, this overview of theory turns to discussions of both *situated knowledges* and *agential realism*, two conceptually resonant discourses that will further enable us to grasp how such enactments are configured within distributed assemblages. Furthermore, folding discourses on *situated knowledges* and *agential realism* into the survey of DeLanda this overview has already performed generates two conclusions moving forward: namely, that assemblages are situated and knowledges are assembled.

In the seminal essay *Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective* (1988), Donna Haraway charged readers not only with insisting on taking "better account of the world", but with reimagining our notions of empiricism in order to both simultaneously account for "the radical historical contingency of all knowledge claims" and still produce "faithful accounts of a 'real' world" (Haraway, 1988, pg. 579). To a large extent—particularly as it pertains to the discussions of knowledge production and the *visual*—Haraway's project is centred on reimagining the perceived relationships of *distance* between an observer, the phenomena being observed, and knowledge subsequently produced. Here the disembodied 'infinite vision' afforded by technologies (from satellites to microscopes) are recast as "god-tricks", or illusionary apparatuses too often capable of compromising untold numbers of distinctly embodied perspectives. In redirecting our attentions to the specificities of the embodied perspectives, then, Haraway comes to claim that "objectivity turns out to be about particular and specific embodiment", that "only partial perspective promises objective vision" (Haraway, 1988, pp. 582-583). The result is a theoretical framework that places a premium on considerations for

[17] For example, how a project like Cherish reliably produces visualisations of heritage landscapes to specific standards of accuracy and formatting.

positionality of the scientific observer or, as Haraway would eventually codify the resulting ethos, as one of “situated knowledges”.

It is important to note, however, that where Haraway elaborates this discussion of *situation* to further address concerns of social performance, gender, or class, these are not concerns that will be explicitly addressed within this thesis. Because this thesis seeks to address the translation of situated knowledges through assemblages distributed across numerous sites of production, it is less concerned with the explicit identities of subjects (i.e., Cherish Practitioners) than it is—after Lucy Suchman—with the “context of particular concrete circumstances” inherent in the material engagements such subjects perform in the generation of digital data and objects (Suchman, 2006, pg. 26). As such, what the thesis explicitly derives from Haraway is the degree to which the notion of “partial objectivity” might inform the material engagements I observed in the generation of archaeological data. *Situation*, then, is taken here to address concerns of haptic interactions with instruments and hardware, and of interactions with physical heritage landscapes mediated via technology, that nonetheless produce partially objective knowledge.

Haraway's epistemology of *situation* also changes how we might think about abstraction within heritage sciences more generally. Rather than advocating a theory of knowledge where "language and bodies both fall into the bliss of organic" or "global systems", Haraway emphasises the need for "an earth-wide network of connections, including the ability to translate knowledges among very different ― and power-differentiated ― communities" (Haraway, 1988, pp. 579-580). Here, the abstraction of knowledge becomes inextricably bound up in the situated contexts where knowledges either were or are produced. These notions have particular importance when considered in concert with *circulating reference,* as both understand the production of knowledge in terms of distribution and translation. What adding Haraway to the conversation accomplishes, however, is an

understanding that any "network of connections" through which knowledges are translated also implies that each node in such a network is defined by its terms of *situation*. Specifically, as it concerns the resulting datasets and visualisations produced through digital heritage research projects (i.e., digital heritage objects), the question of situation will here also be considered in concert with the attendant discussions of emergence detailed in the previous section. Doing so helps to define how the iterative development of digital heritage objects ― and the knowledges carried by them ― can be further understood by specifically targeting the interchanges and interactions that occur as knowledges are translated between and across situations.

For theoretical physicist Karen Barad ― much of whose work deliberately seeks to develop Haraway's concept of situation ― the project of practicing science while also acknowledging the inherent contingency of all knowledge claims requires inextricably linking the performance of scientific inquiry to the knowledges extracted through such efforts. Here both theory and experiment are re-tooled in terms of their mutual and individual correspondence to notions of both “intervention” and “intra-action”. Barad’s discussion of “intervention” is principally derived from the writings of Ian Hacking who, in an effort to “disentangle realism from its traditional representationalist formulation”, sought to foreground experimentation as a complex system of material engagements, performances, and practices (Barad, 2007, pg. 51; Hacking, 1983). Within Barad’s reading of Hacking, representational realisms fail to account for the practices through which representations (such as scientific imagery) are generated. As such, Barad, via Hacking, contends that “images or representations are not snapshots or depictions of what awaits us but rather condensations or traces of multiple practices of engagement” (Barad, 2007, pg. 53). Much of this pertains to the “proto-perfomativity” Barad locates in the philosophy-physics of Niels Bohr, which is deployed in *Meeting the Universe Halfway* (Barad 2007) as something of a conceptual north

star. Here concepts, just like experiments, are framed as being similarly contingent upon "specific physical arrangements". Any abstracted concept, such as the 'position' of a particle in motion, for example:

> …cannot be presumed to be a well-defined abstract concept; nor can it be presumed to be an individually determinate attribute of independently existing objects. Rather, position has meaning only when an apparatus with an appropriate set of fixed parts is used. And furthermore, any measurement of position using this apparatus cannot be attributed to some abstract, independently existing object but rather is a property of the phenomenon—the inseparability of the object and the measuring agencies (Barad, 2007, pg. 139).

As such, the emphasis placed here on the co-constitutive or agential role of 'phenomena' in the derivation of either measurement or theory is central to the pivot Barad makes towards a unifying notion of "intra-action". It is a move that foregrounds entanglement, dramatically reconfiguring the perceived *distance* between an observer and the phenomena observed. (Which is likewise both derived from, and further elaborative of, Haraway's notion of "partial objectivity"). Furthermore, it is also foundational to one of the more striking and instructive philosophical notions developed within the text overall. Deferring again to Bohr's philosophy-physics, Barad elaborates the notion of "complementarity" to construct a radical theory of knowledge production. As one of the central notions within Bohr's larger theory of quantum physics, the law of complementarity contends that any particle in motion cannot have simultaneously determinate values. The very act of measuring a hypothetical particle's position, for example, means the same particle's momentum becomes necessarily unmeasurable. As a result, the material entanglement required to either perform scientific measurement or produce reliable descriptions of observed phenomena rejects or negates any supposed representational distance between the production of knowledge and the knowledges produced. The implication of this, for Barad, is profound:

> Bohr argues that scientific practices must therefore be understood as interactions among component parts of nature and that our ability to understand the world hinges on our taking account of the fact that our knowledge-making practices are social-material enactments that contribute to, and are a part of the, the phenomena we describe (Barad, 2007, pg. 26).

Rather than a scientist or technician 'intervening' in an already present phenomenon in order to derive some measurement or piece of data, Barad contends that ─ simply by virtue of performing an observation or measurement ─ the observer and the phenomena being observed become inextricably bound to one another. As such, part of what Barad and *intra-action* enables us to do is account for how the performance of activities comes to co-constitute the assemblages this thesis targets. As a further consequence, assemblages are in turn revealed as themselves being defined by situation.

This is central to the core ontology of *Agential Realism* Barad develops and delivers throughout *Meeting the Universe Halfway*. This ontology roundly challenges centuries of metaphysical thought grounded in, or presumptive of, atomistic ontologies composed of individual entities with discrete and self-contained properties. It is further generative of unique epistemological consequences, as well. Barad's notions of measurement, for example—as a result of its perceived relationship to logics of intra-action—necessarily rejects the idea of measurement as a performance of intervening in a pre-existing always already present phenomenon. As a result, measurement is re-thought here as neither representing a given "state of affairs" or "measurements of independent states of being", but an intra-action between the phenomena observed and the observer (Barad, 2007, pg. 138). Crucially, however, Barad's suggestion of a realist account of the universe where relational phenomena, rather than "things", are established as the primary ontological units is still grounded in notions of configuration and arrangement. Instantiations of phenomena are given here as units (specifically termed as "*relata"*); units which possess the capacity to both relate

to one another and hold distinct capacities to be generative of emergent properties by virtue of their relationality:

> In other words, relata do not preexist relations; rather, relata-within-phenomena emerge through specific intra-actions. Crucially, then, intra-actions enact *agential separability*—the condition of *exteriority-within-phenomena.* The notion of agential separability is of fundamental importance, for in the absence of a classical ontological condition of exteriority between observer and observed, it provides an alternative ontological condition for the possibility of objectivity (Barad, 2007, pg. 140).

The affordances made here towards concerns of exteriority, or the configurations of relational phenomena, not only resonate with Haraway's discussions of both partial objectivity and situated knowledges, but also enable us to consider agential realism and situated knowledges within the context of assemblage theory. The converse of this is that it likewise enables us to elaborate our understanding of assemblage theory through terms of situation, intra-action, and agential realism. Not only does intra-action insert the performance of measurement or observation into our general understanding of what can comprise a given assemblage, it mandates that we define the relationality of assembled components in terms of site-specific contingencies and contexts. Conceptualising assemblages with situation also changes how we might consider that which emerges as a result of their co-functioning. In the context of digital heritage initiatives and the objects they likewise produce, if the intra-action of assembled components describes the conditions of exteriority DeLanda ties to emergence, it follows that emergence should also be defined in similar terms. Therefore, the digital heritage objects this thesis considers, for example, should likewise be discussed in terms of situation.

To begin illustrating how situation or agential realism impacts the emergence of digital heritage objects it is helpful to return again to assemblage theory, specifically as it has been taken up by contemporary theoretical archaeologists. From the 1980s onwards, scholars of either "post-processual" and "behavioural" archaeology have expanded their discipline's more traditional definitions of the term (see above) to correlate the performance or "doing" of

archaeology with attendant discussions of materialism and the production of the "archaeological record" (Fowler, 2013; Fowler and Harris, 2015; Hamilakis, 2017; Hamilakis and Jones, 2017; Harris, 2017; Hodder, 1982; Hodder, 1997; Lucas, 2012; Renfrew et al., 1993). By foregrounding discussions of "relational realism" in their discourses of methodological archaeological practice, such scholars also conceptualise the abstraction of archaeological knowledges in ways that resonate with Haraway and Barad (Fowler, 2013). Relational realism in the context of archaeology re-configures the ontologies formally associated with both material finds and/or the production of the archaeological record. Here such ontologies are re-thought as being process-based and mutually emergent via the performance, doing, and the enactment of material engagements with artefacts, sites, and monuments.

Yannis Hamilakis, for one, defines archaeological assemblage as the co-functioning of both material and immaterial components activated through site-specific engagements (*intra-actions*, in Barad's terms) between archaeologists and archaeological artefacts (Hamilakis, 2017). More specifically, the material components typically taken to define an archaeological assemblage (artefacts/monuments, instruments, and tools) are here re-thought as being co-constitutive of *immaterial* constructs of meaning (memory, knowledge, history) as a direct result of performed social-material intra-actions. Much of this is bound up in how archaeology has come to discuss the relationship between practices of experiment and interpretation. Dating to the early 1980's, a new wave of archaeological scholarship—pioneered, in part, by Ian Hodder—sought to resolve a perceived contradiction inherent in the presumed processual movement of empirical investigation and subsequent interpretation. Simply put, "post-processual" archaeology contends that there can be no "objective" derivation of data (Carver, 1989; Hodder, 1997). In conceptually pushing interpretation "to the trowel's edge", Hodder further contended that doing so restructures archaeological

fieldwork around concepts of reflexivity, contextual relationality, and plurality (Hodder, 1997). The legacy of these tenets is more than evident within the discipline's contemporary discussion of assemblage theory. Here, notions of performance, process, and materiality are thought through together in order to consider the production of archaeological knowledge in tandem with notions of situated contingency and the material extension of "the archaeological record" (Lucas, 2012; Patrik, 1985). Given the propensity of assemblage thinking possesses for theorising unstructured or semi-structured socio-material configurations, scholars like Gavin Lucas, for example, have used assemblage thinking as a means to enliven archaeology's relationship to its material components in dynamic and inter-relational ways:

> The focus on performance, both by behavioural archaeologists and the French school, helps us see that what really matters is perhaps not materiality but materialisation, a process through which objects and people are made and unmade, in which they have no stable essence but are contextually and historically contingent […] in this sense, objects always hold something in reserve, they are always both virtual and actual entities simultaneously… (Lucas, 2012, pp. 166-167).

Additionally, a theory of assemblage derived from post-processual traditions produces significant consequences for how the relationship between an archaeological "object" and its abstraction into "the record" might likewise be considered. As it concerns that which emerges from an archaeological investigation, a theory of assemblage grounded in affordances for performance and "materialisation" necessarily changes the way in which the knowledges generated through the *doing of archaeology* might be understood. Speaking specifically to the material components of an archaeological assemblage, Chris Fowler frames the relationship between source "objects" and abstracted knowledges/records within a grammar of "extension" that elaborates DeLanda's notions of exteriority/emergence:

> But further, archaeological practice engages with the remains of the past in such a way to extend, to draw along, the traces of past relations that endure in the evidence from one configuration to another. Photographs of objects and places, context sheets,

> site plans, drawings of objects, and writings describing archaeological remains are all translations, transformations, extensions, and transfers of the remains themselves. Some properties of the remains are translated and preserved through the recording process, and through this process some features of the past object survive and become extended (Fowler, 2013, pg. 5).

Fowler's terminology of translations, transfers, and/or extensions are also evocative of the process-based ontologies he incorporates elsewhere in his scholarship (Fowler, 2013; Fowler and Harris, 2015).

Process-based understandings of archaeology become particularly potent when considered in the context of the eroding heritage landscapes this thesis targets as case studies. Not only are such heritage sites — by virtue of their ongoing collapse and decay — dynamic systems defined, in part, by their propensity to rapidly alter or change, but such dynamics likewise determine how and why practitioners study them in the first place.[18] For geographer and heritage scholar Caitlin DeSilvey, questions about heritage preservation/conservation should more actively reflect and respond to questions about material processes. DeSilvey challenges prevailing notions about heritage conservation by contending that heritage objects — from the artefactual to the monumental — should be understood as dynamic, rather than static, material systems (DeSilvey, 2017). Specifically, as it concerns how people relate to heritage sites/objects, she advocates for "a wider cultural recognition that we need to find ways to inhabit change rather than deny or deflect it" (DeSilvey, 2017, pg. 14). DeSilvey is further sceptical of prevailing notions of heritage which link "materiality, memory, and subjectivity through mutually reinforcing chains of reference" (DeSilvey, 2017, pg. 14). It is a move which challenges key aspects of *circulating reference* as being too focused on 'transitive' processes, rather than generative ones. Furthermore, in actively rethinking the relationship between the material and memorial so often associated with heritage

[18] In fact, a large majority of digital heritage initiatives are often centred on the preservation/conservation of "threatened" heritage spaces. Groups like Iconem (http://iconem.com), for example, have used similar methods to those described in this thesis to digitise and preserve heritage sites and monuments threatened in armed conflicts across the globe.

sites/objects, conservation initiatives can become less centred on the idea of "stable" material forms (DeSilvey, 2017). Applying DeSilvey to the consideration of digital heritage initiatives is significant because the digital objects produced by such efforts not only actively seek to capture and monitor change and alteration (as with the Cherish Project) but are themselves defined by the conditions of mutability and multi-sitedness inherent in their digitality.

Thus far this chapter has reviewed assemblage theory to both address the distribution of workflows used in digital heritage science and to better conceptualise how the knowledges produced through such practices emerge. It has consulted scholarship on situated knowledges and agential realism to both situate the site-specific material engagements/performance of method or protocol within a broader understanding of these assemblages, *and* to further associate situation with emergent objects and knowledges. Specifically, this relationship between situation and emergence has been further elaborated by deferring to archaeological understandings of assemblage theory. Here the discussion of both material objects and abstracted knowledges is further grounded in iterative and process-based ontologies centred on discussions of performance and materialisation.

Because of both the multi-sitedness of their production — as well as the mutability of the data from which they are derived — digital heritage objects provide a potent and accessible means to illustrate and explore the inter-relationships of theory thus far reviewed in this chapter. However, because the production of digital heritage objects is inherently multi-sited, it also follows that the situated nature of the datasets which comprise them undergo significant translations and rearticulations as they as travel across sites of production (often entering into new situated contexts as a consequence). As such, this review of literatures will next consult scholarship concerning the ontologies of digital objects. In so doing it will specifically focus on the processual formalisation of the situated datasets into cohesive wholes or objects. As a term used both within the remaining sections of this chapter

and throughout the empirical chapters of the thesis, the *formalisation* of digital heritage objects refers to the iterative refinement and eventual coherence of datasets and images as they are integrated, eventually composing "objects" with distinct applications for research and outreach.

2.4 Digital Heritage Objects (From Epistemic Things to Technical Objects)

This thesis understands the distributed workflows of digital heritage initiatives (like the Cherish Project) as being composed of situated assemblages which generate emergent datasets. These datasets carry traces and inscriptions of the knowledges specific to the configuration and co-functioning of the assemblages that produced them. The inscriptions of these knowledges are commonly expressed both through the primary information such data is designed to carry (geo-spatial coordinates or digital images, for example) and through the metadata schemes embedded within them (details on how and when such data was produced, for example). As these datasets travel between and across these distributed sites, however, they are recombined and processed in order to produce digital heritage objects with specific uses and applications. Following digital geographer Rob Kitchin's contention that metadata describe the "lineage and provenance" of how data is derived ─ as well as media theorist Yuk Hui's claim that digital objects are "formalised by metadata and metadata schemes" ─ the cohesion of digital objects is therefore predicated on the systematic assembling of the situated knowledges inscribed in the various datasets used to compose them (Kitchin, 2014b, pg. 9; Hui, 2016, pg. 26). As such, the theories consulted below not only address how digital object-ness is predicated on unique articulations of assemblage specific to data and software, but how processes of translation and cohesion facilitate the emergence of knowledges that become serviceable and applicable in research contexts outside of the workflows that produced them.

In her richly detailed ethnography of crystallographic modelling laboratories *Rendering Life Molecular* (2015), Natasha Myers uses both situated knowledges and agential realism as a means to untangle the dense relationship between scientists, the technologies and instruments they use, and the outputs they produce. Very much in line with Haraway, these efforts are often described by Myers in terms of the partial, active, or detailed ways in which they "render" their molecular subjects accessible and useful to researchers.

Three-dimensional crystallographic modelling is presented by Myers as being centred on unique configurations comprised of technical instruments, powerful softwares, and performative human engagement. And while Myers doesn't explicitly discuss assemblage theory within her text, her descriptions of these configurations resonate with much of the way assemblage has so far been discussed in this chapter. Furthermore, the unique fitting together of instrument and intra-action is constitutive of an apparatus Myers collectively considers as a “human-computer-lens”: a device developed to address both the socio-technical entanglement inherent to modelling and the co-produced nature of the models themselves (Myers, 2015). Specifically, as it pertains to notions of "rendering"[19], however, the necessarily situated or partial nature of the ‘vision’ this apparatus provides necessitates a discussion of the models they produce that goes beyond considerations of the "mimetic". Protein crystallographers “do not ‘see’ molecules or produce ‘images’ of biological phenomena; rather, they *make* models to *render* the molecular world visible, tangible and workable” (Myers, 2015, pg. 18). As such, part of what Myers points to is the distinctly performative and materially entangled ways in which protein modelers engage with the content of their study, a process delineated as being both inherently embodied and affective. Additionally, in contending that a 3D model “can be thought of as a record of the intimate

[19] Throughout the text, Myers’ uses the verb ‘to render' to alternately capture notions of representation, making, performance, or delivery.

knowledge its modeler gained during its production", Myers hits upon the ways in which models and their attendant meanings can evolve from "epistemic things" to both "technical objects" and aesthetic visualisations as they migrate into other experimental contexts (Myers, 2015, pg. 78).

Myers' derives the terms "epistemic things" and "technical objects" from Hans-Jörg Rheinberger's text *Towards a History of Epistemic Things* (1998), a work which specifically addresses relationships between the writing of science and experimental laboratory processes. For Rheinberger, the "doing" of science — and of experiment — is characterised as a process of "reorientation and reshuffling of the boundary between what is thought to be known and what is beyond imagination" (Rheinberger, 1998, pg. 11). Experiment, in particular, is typified here as circular and processual system through which knowledge is first derived and then imposed back into similar circumstances for deriving *further* knowledges. Specifically, Rheinberger develops the terms of "epistemic things" and "technical objects" to illustrate the cyclical process of derivation and (re)imposition he describes. Epistemic things are here not only discussed as the products and/or results of experiment (which Rheinberger also describes as "scientific objects") but are further defined as both "inscriptions" and "traceable conformations", which bear the provenance of how measurement and observation were initially derived (Rheinberger, 1998, pg. 111). Crucially, however, epistemic things have the capacity to become "technical objects" if they serve to develop demonstrable truth claims. This translation is defined by whether and when they become instrumentalised and reinserted back into an experimental system:

> ...experimental systems "contain" the scientific objects *[ie, epistemic things]* in the double sense of this expression: they embed them, and through that very embracement, they restrict and constrain them. Superficially, this constellation looks simple and obvious. But the point to be made is that within a particular experimental system both types of elements are engaged in a nontrivial interplay, intercalation, and interconversion, both in time and in space. The technical conditions determine the realm of possible representations of an epistemic thing; and sufficiently stabilised

> epistemic things turn into the technical repertoire of the experimental arrangement (Rheinberger, 1998, pg. 29)

In the context of this research, then, epistemic things are here understood as the emergent outputs produced through Cherish practices (data, images, etc.) *before* they are formalised for distinct application in analysis or outreach. Once formalised as 3D models or DEMs, however, such outputs are understood as technical objects. Meaning that once processed to a certain point, configurations of processed Cherish data are capable of both leaving the assemblages and workflows that produced them and further functioning as key components in other epistemic work. Given how digital heritage objects are often produced as tools of analysis or interpretive learning, once formalised as 'technical objects' they, too, are often reinserted into new experimental arrangements which can likewise be described as knowledge-producing assemblages. For Rheinberger, whether a scientific object functions as an epistemic thing or a technical object "depends on the place or 'node' it occupies in the experimental context" (Rheinberger, 1998, pg. 30). The translation from one to the other, however, is not without ontological consequences for these scientific objects. As inscriptions and traceable conformations, when epistemic things are translated into technical objects they become "standardised, reduced, purified, isolated, contracted, and monofunctionalised entities that can be transported and subjected to local modifications" (Rheinberger, 1998, pg. 109).

This transition, from "epistemic things" (i.e., a record of knowledge gained via its production) to "technical objects" (i.e., tools with the potential for both theoretical and practical applications), points to one key question this thesis poses: namely, when, where, and how the digital heritage data cohere as digital heritage objects. Myers' text is helpful not only in that it provides clear examples about how notions of situation and/or agential realism come to be articulated in observed cases, but how these conditions are mediated by the fitting together of instruments, technologies, and subjective material engagement. In specifically

targeting how situation defines the assembled "human-computer-lenses" crystallographers use to conduct their experiments, Myers further demonstrates how situation comes to be inscribed in the data and outputs they likewise produce. Furthermore, Myers (via Rheinberger) presents the conceptual tools necessary for understanding how situated engagements in experimental systems produce scientific objects which can iteratively evolve into applicable tools and instruments for further research and analysis. As it applies to our consideration of the digital heritage research and the processual cohesion of the digital heritage objects, however, the translation of epistemic things to technical objects is determined by the assemblages inherent to specific sites of processing and visualisation. As such, in order to further develop notions of digital object-ness moving forward, we'll now consider how the configuration of components like platforms and software used for the modelling of digital heritage objects facilitate the translation of digital heritage data form epistemic things to technical objects.

With very few exceptions, the outputs of digital heritage initiatives are analysed, circulated, and used via screens, interfaces, browsers, software, and platforms. As data travels between storage databases and modelling softwares, for example, datasets are duplicated, reformatted, and altered in significant ways. Often this is to conform to the processing requirements of softwares and interfaces used to visualise and process such data. In many instances only certain aspects of a given dataset are accessed and used by a given application, meaning the functionality of a dataset as an input is determined by what the corresponding platform or interface is designed to do with that data. As a result, this thesis's discussion of a digital object requires some disclaimers and clarification. Digital-visual objects ― as opposed to non-digital visual objects ― are uniquely unstable and ontologically multiple, often defined by their mutability, multi-mediality, and mass (Rose, 2016). Every time digital visual information ― such as simple image (.jpeg, .png, etc.), for example ― is accessed on a

browser, it is reconfigured to the specifications and particularities of the devices and services used to interface it (Steyerl, 2012). In their own discussions of networked or computational "things", Heather Wiltse and Johan Redström describe this very mutability and multiplicity as being inextricable from their understanding of digital objects:

> With respect to such characteristics of assemblages and assembling, not only do our networked computational things combine a range of technologies, computation, communication, sensors, interfaces, etc. to become what they are, they also make use of resources in a variety of places, both geographically and thematically, and on top of all these they very much operate on the basis of the social fabric of everyday life. But whereas our traditional things are mostly totalities—stable wholes that cannot be taken apart as they are made of parts that have given up their individuality—these computational things are to significant extent built (in runtime!) using components that retain theirs: that can be recombined, reused, and thanks to digital technology even be made active in many places at the same time (Wiltse and Redström, 2016, pp. 67-68)

Acknowledging this mutability not only points to the fluid contingencies defining the assemblages of the numerous components involved in either the circulation or use of heritage data, but complicates how we can understand and talk about any digital object. Given the multiplicity and mutability of digital visual objects, the consideration of the key outputs as either epistemic things or technical objects raise several key questions: When, and at what stage, for example, does a series of relational yet individuated datasets (primarily composed of images, scan points, and coordinates) assume coherent forms used in distinct research contexts? When and why do the terms of this cohesion change? Finally, how do instances of situated material engagement with digital-visual data factor into these processes of formalisation, and how are records of these material engagements propagated throughout these respective processes?

In order to address these questions ahead of their explicit consideration in the empirical chapters that follow (specifically, Chapter 6), I will begin by drawing on the work of media theorist Yuk Hui, whose recent scholarship has broadly addressed the ontologies of digital objects (Hui, 2012; Hui 2016). As alluded to above, metadata and metadata schemes

are presented by Hui as one of several key agents in the formalisation of data as objects. Metadata (often defined using the pervasive shorthand "data about data") have been further described by Rob Kitchin as the means through which the user of a dataset can "understand its composition and how it should be used and interpreted, and facilitates the conjoining of datasets, interoperability and discoverability" (Kitchin, 2014b, pg. 9). Hui specifically addresses the function of metadata in the formalisation of data objects in terms of what he describes as the "objectification of data" and the "datafication of objects" (Hui, 2016). As it relates to digital heritage objects, *datafication* concerns the numerous processes through which the measurement and observation of physical objects become translated as digital information. As such, the initial acquisition of archaeological data conducted at field sites—either through drone photogrammetry, GNSS survey, or laser scanning—can here be understood within the context of Hui's notion of the "*datafication of objects*". The *objectification* of data, by comparison, addresses the processes wherein data is categorically tagged ─ through metadata schemes ─ into configurations that hold meaning (Hui, 2016). Within the context of the modelling practices this thesis addresses, the distinction between the *datafication of objects* and the *objectification of data* helpfully articulates something of the double move that is predicated by the transference of data between sites of either acquisition or processing. Simply put, the acquisition of data in the field largely concerns the datafication of objects (meaning, the heritage features such practices target), and the stages of processing and rendering of that same data largely concerns their subsequent *objectification*. Crucial for Hui, however, is the contention that digital things can still be considered objects before being objectified by metadata schemes, contending, rather, that it is within metadata schemes "that they are *formalised* as objects through human agency and then *recognised* as objects by computers" (Hui, 2016, pg. 50, emphasis added). The determining factor of human agency proposed here is further bound up in Hui's aim of constructing an understanding of

digital objects that extends beyond ontologies that strictly understand "objects" as compounds of matter and form (which Hui links to the Aristotelian concept of *hylomorphism*). Contrasting these notions with Gilbert Simondon's suggestion that a tool is not only composed of matter and form, but is further constituted from a certain system of usage, Hui claims that:

> much as we know that mass production is mainly based on moulding and the form-matter logic inscribed in it, technical process cannot simply be explained by the principle of hylomorphism. The identity of a technical object equates to the totality of its production as opposed to its form and matter (Hui, 2016, pp. 61-62).

In moving beyond a hylomorphic understanding of the composition of digital objects, Hui opens the door for considerable insight into how our understanding of digital objects should likewise be informed by attending to how they are produced and circulated.

For Hui, any consideration of digital objects also requires acknowledging something of their inherent duality. Any given digital object commonly has two articulations: that which is accessible to a user through an interface (a "front end" articulation), and that which is accessed by the computational components of an interface (a "back end" articulation) (Hui, 2012, Hui 2016). The many digital objects that flicker daily through our screens—such as Instagram stories, media-based tweets, or the 3D heritage models this thesis concerns—possess a sensible iteration as they exist in the context of an interface's display: the images and models we see and engage with as users. Yet inherent to every visualised digital object are sequences of embedded semantic information (such as metadata and code) not readily accessible to users in their reified visual forms. For Hui, the project of theorising digital objects[20] is contingent upon first considering their respective processes of "becoming" within a grammar of relational materiality and varying orders of what he terms "milieux". Hui's use of milieux, as a catch-all term, is centered on the consideration of the numerous components

[20] It should be noted here that Hui uses the terms "data objects" and "digital objects" somewhat interchangeably.

(software, hardware, etc.) necessary to formalise digital objects. As such, it is here taken to correlate with the notions of assemblage this review has already developed. Hui refines his definition of the 'digital milieu' in contrast to historical discussions of phenomenology, technology, and cybernetics, further targeting the work of Simondon as being particularly instructive. Here, the inter-relational and processual actualisation of digital objects—connected and linked through series of protocols and standards—generate a multiplicity of "enframing networks" (Hui, 2016). Part of what Hui actively attempts to recalibrate here is the notion—largely derived from traditional cybernetics—that informational networks are inherently immaterial by virtue of the supposedly atomised bits of information that compose them. Hui, by contrast, not only closely associates terms of relationality with his understandings of the material but contends that digital objects are both generative of ─ as well as being derived from ─ their associated milieux. Or, more concisely, he contends that digital objects "are at the same time logical statements and sources for the formation of networks" (Hui, 2016, pg. 25). In arguing that digital objects are generative of milieux by virtue of conditions of relationality, Hui begins to define digital objects in a manner that resonates with the way this thesis has begun to consider both relationships of exteriority and emergence (DeLanda) and the situated nature of assemblages more generally (Barad, Haraway). Put simply, neither the cohesion of the digital heritage object, nor the assemblages inherent to its production can be considered in a vacuum; just as the intra-action of components assembled define and produce emergent digital objects, so does the object define its corresponding assemblage (or milieu, in Hui's terms). As a result, Hui also provides a theoretical means for understanding how the co-constitution of both emergent digital objects and their corresponding assemblages facilitates the formalisation of data (or epistemic things) as relationally defined digital objects (or technical objects).

Hui develops these terms of relational object cohesion by further adapting Simondon's discussions of *individualisation* and *individuation* to an explicitly digital context (Hui, 2016). After Simondon, *individualisation* is here taken to address an object's capacity for differentiation, wherein a digital object individualises "by adopting and creating an associated milieu to stand independently" (Hui, 2016, pg. 58). Individuation, by comparison, speaks to a digital object's capacity to sustain a given equilibrium within the potentially fluctuating conditions of a given milieu (Hui, 2016). In order for an object to become individualised, then, it first needs to define itself both within the context of its own composition and in relation to the milieu with which it is associated. Individuation, in contrast, develops specifically as a consequence of the larger relational conditions of the collective assemblage in which the object is placed. It is a subtle distinction, but an important one. To illustrate, let's consider a hypothetical photogrammetric model of a heritage monument. Such a model becomes *individualised* by virtue of its own compositional elements (i.e., the collective relationship and orientation of the individual images and spatial coordinates that define its shape and appearance). The same hypothetical model, however, might also be understood as becoming *individuated* by virtue of its collective composition's relationship to the framing conditions of a digital workspace (i.e., the organisational spatial properties of something like the geographical coordinate system to which it is referenced, or the uniformity of file types for its inputs and outputs). In a manner that is also resonant with Barad, given the agential capacity for digital objects to compose and "transform referential relations in material forms", the network generated through the "inter-objectivity" of the images and coordinates composing a photogrammetric model are likewise constitutive of the assemblage/milieu/network that would make its individualisation and individuation as a compositional object possible (Hui, 2016, pg. 25).

In the project of applying Myers and Rheinberger's notions of epistemic things and technical objects to our understanding of the cohesion of digital heritage objects, then, Hui complicates things. As epistemic things, digital heritage datasets become individualised or individuated ─ which is it say, formalised as objects ─ by entering into situated configurational assemblages for specific reasons at specific moments. Following Rheinberger's claim that as epistemic things become technical objects they are "standardised", "reduced", or "monofunctionalised", it necessarily follows that such transformations are both contingent upon and generative of diverse and relational assemblages of softwares, interfaces, and more. In a sense, then, we have come full circle. In Myers and Rheinberger we have located

theoretical language to not only describe how knowledges emerge through the intra-action of situated material engagements with socio-material assemblages ("human-computer lenses"), but also how situated and emergent knowledges are translated and instrumentalised in order to become tools for further research ("epistemic things"/"technical objects"). In Hui we have further located conceptual tools for understanding how "epistemic things" and "technical objects" are related to the cohesion of digital objects. Hui not only crucially links the "objectification of data" with the formalisation of metadata schemes through relational and intra-active assemblages (or "milieux"), but further claims that it is through such processes that digital objects become recognisable to computers. In short, the configurations of the assemblages/milieux inherent in digital objects, the involvement of situated material engagement necessary for their production, and their respective capacities for application and use are all critically linked. As such, the discussions of assemblage theory, situated knowledges, or agential realism this chapter has already reviewed become particularly helpful for situating the translation of "epistemic things" to "technical objects" within the context of digital objects. Furthermore, using these literatures collectively enables us to not

only consider how physical heritage landscapes and monuments come to be translated by archaeologists as digital visualisations, but to consider how the knowledges such visualisations can carry are constituted.

2.5 Assembling the Theories Reviewed

The collective theoretical orientations outlined in this chapter (*assemblage*, *situated knowledges*, and the *ontologies of digital objects*) have been organised and presented in order to elaborate and enrich the underlying research questions this thesis considers. In the project of addressing both how digital heritage objects are produced and how their knowledges are co-constituted, these orientations enable us to focus on the following:

a.) Developing the means to address the production of both digital objects and archaeological knowledges via workflows and practices that are distributed across multiple sites of production and facilitated through the translation of datasets defined by their mobilities and mutabilities.

b.) How the distinct configuration of *assembled* components results in the emergence of specific types data, knowledges, and digital objects via the intra-action between assembled components.

c.) How the constitution of these knowledges is not only socio-materially constructed, but articulated through terms of partiality and *situation* that define the site-specific performance enacted by digital heritage practitioners.

d.) How both the configuration of perceived assemblages and the terms of situated engagement inherent in such is inscribed, iteratively translated, and articulated as unique knowledges as the data produced coheres as digital heritage objects.

Beginning with Latour's notion of *circulating reference*, this chapter has established the theoretical tools to trace the derivation of knowledge, data, and digital objects across multiple sites of production. Not only does the permeability Latour locates between field sites and laboratories enable us to understand how assembled frameworks of reference (like the spatial registers discussed in Chapter 4 of this thesis) become mobile and transitory between sites of production, it enables us to consider a multi-sited research collectively and cohesively.

In order to more carefully consider the iterative abstraction of archaeological models and knowledges in generative rather than transitory terms (a necessity given the mobility and mutability of digital heritage data, and a crucial aspect to how this thesis uses Latour's *circulating reference*) this chapter has also considered discussions of assemblage theory as it has been taken up by scholars of archaeology, geography, and philosophy. Through its overview of Manual DeLanda, it developed an analytical toolkit centred on notions of *exteriority*, *emergence*, *territorialisation*, and *coding*. This toolkit, as will be evidenced in subsequent chapters, can be effectively applied to decipher how and where assemblages cohere, become defined, or remain generative of emergent properties. It also uses geography's grammar of assemblage thinking to describe the instable and fluid nature of the socio-material assemblages it identifies within digital heritage projects; using the discipline's attendance to process-based understandings of assemblage to refine and develop the tools necessary to trace the mobility and multi-sitedness of the processes discussed throughout the empirical chapters. Finally, it is the notions of assemblage derived from theoretical archaeologists in order to situate the site-specific material engagements performed by digital heritage practitioners within the larger socio-material/socio-spatial assemblages that define such work. Taken collectively, the overview of assemblage presented here functions to trace

the co-production between and across the numerous sites, procedures, and methodologies observed during this thesis's fieldwork.

In the writings of Donna Haraway and Karen Barad, the overview of literatures here takes up notions of *situation* and *agential realism* in order to consider not only how knowledge is produced through Cherish activities, but how such knowledge should be understood in terms of the positionality and partiality defining the performance of methodologies observed. Furthermore, it challenges any presumed notion of a representational distance separating the performance of prescribed methodologies from the knowledges abstracted through their enactment. Specifically, as these texts relate to theories of assemblage derived from archaeological discourse, something this overview also has produced is a nuanced understanding of both how situated knowledges also come to be *assembled*, and how the configuration and/or terms of *situation* then come to endure through the abstraction of knowledge and its subsequent inscription in data.

All of the above is further compounded in the overview's discussion of the ontologies of digital objects, where notions of *epistemic things, technical objects, data individualisation*/*individuation*, the *datafication of objects*, and the *objectification of data* are introduced in order to consider what data objects "are" and how they come to be. The theory collected here not only points to how data objects, in many respects, are a "material" condensation of their respective means of production, but how the terms of their constitutions are defined the instability and fluctuation of assemblages that produce and reproduce them.

Taken together, then, the unique configuration of literatures here reviewed provide the means to effectively theorise the observed site-specific enactment of digital heritage methods within the context of larger and distributed assemblages that enframe them, all while simultaneously tracing the inter-relationship of both through the processual derivation of digital objects. This assemblage of theory was instrumental to the planning and enactment of

my own fieldwork. Furthermore, it was more than instructive in the analysis of the data my fieldwork produced, as will be evidenced in the empirical chapters to follow.

In addition to the literatures reviewed here, each empirical is further informed by subsequent theoretical texts *not* exhaustively discussed in this chapter. In Chapter 5, for example, several works by John Law are reviewed as part of a discussion on the relationship between digital spatialities and digital objects in stages of rendering and post-processing. Moreover, the works of Gillian Rose and Rob Kitchin are extensively reviewed as part of the discussion of the mobility and ontological multiplicity of data and digital objects taken up in chapter 6. The reason such discussions have been embedded in the empirical chapters — rather than here — is that they serve specific analytical functions to the empirical findings produced through my fieldwork. Simply put, they are better developed in parallel with the data they help to elaborate.

The subsequent chapters of this thesis will address the following points. They will describe the dispersion of "sites" across a given observed method. They will then trace the production of distinct spatial registers resulting from the enactment of key procedures which practitioners perform to spatialise heritage sites. Finally, they will also detail the inscription and translation of these spatialities within the data produced as it coheres into "discrete" forms. As such, the concepts and terms developed here all prove instrumental in illuminating how the knowledges the Cherish Project produces, and continues to produce, come to be constituted.

Chapter 3: An Overview of Methods

3.1 Introduction

The process of designing fieldwork for my study of the Cherish Project and selecting the methodological toolset best suited to explore my research questions began with taking careful account of what I understood about the project and its work at the outset. As mentioned in the preceding chapter, before heading to Dublin for the first time I had conducted several informal interviews with Discovery's technology manager Anthony Corns over Skype. In these conversations he had not only outlined the broad strokes of Discovery's involvement in Cherish, but had also directed me to relevant online materials concerning the project overall[21]. Both in his own words and through the materials he had sent along, the active investigation of Cherish sites and their subsequent translation into digital-visual objects seemed to suggest paying attention to several key factors. Firstly, the work Cherish pursues is inherently multi-sited, meaning that both Cherish data and Cherish practitioners travel from on-site locations to workstations and offices, with processual distribution of the data occurring across an array of instruments, software platforms, and interfaces. Secondly, the iterative and multi-sited work Cherish practitioners perform can be further defined as a series of site-specific material engagements between practitioners and the features they target, the instruments and technologies they use to produce data, *and* with the resulting data itself. Finally, following the data across its sites of production is the most expedient way of not only deciphering the relationships between these perceived sites and engagements, but of further comprehending both the configuration of the assemblages inherent in Cherish work *and* the emergent digital objects such practices produce.

Given these factors, fieldwork would require an aspect of being embedded in the processes observed through participant observation. The question, then, became one of how

[21] Both the official Cherish website (http://www.cherishproject.eu), for example, as well as recent papers publish by both himself and Robert Shaw.

best to relate to my respondents, the processes being enacted, and the data produced throughout these iterative stages. Much of this, I felt, was further couched in the necessity of generating fundamentally different types of data. In one respect — particularly as it concerned the situated orientation of practitioners to both the performance of their tasks and the data produced — there was a pronounced need to give respondents the opportunity to speak for themselves – to account for their relationships to project protocol and methodologies in their own words. As such, this need was deliberately addressed by grounding a significant portion of my fieldwork around *semi-structured interviews*. These interviews were staged in a variety of contexts. They were held in conference rooms, at the desks of respondents as they worked, and on the way to and from field sites. These different settings provided my respondents with different opportunities to not only explain how specific methods were achieved, but something approaching a more narrative-based justification for *why* specific protocols or approaches were enacted in specific ways. In order to balance the data generated through semi-structured interviews, my fieldwork was further structured around *on-site participant observation* (generally meaning I would help out on location where and as best as I could). Where the semi-structured interviews provided respondents with the opportunity to self-report on their activities, participatory observation would provide a means to study the enactment of the protocol such discussions had described from my own perspective. Before beginning my fieldwork, for example, I had completed a series of courses in digital visualisation methods used in the heritage sciences at the University of Brighton. Organised by the centre for doctoral training, Science and Engineering in Arts, Heritage and Archaeology (SEAHA), these practice-based tutorials served as comprehensive introductions to multi-spectral imaging, photogrammetry, and structured-light scanning. Furthermore, long before beginning even attending graduate school, I had both undertaken a certificate programme in GIS and geospatial sciences at

Pasadena City College and worked as an intern GIS technician with the United States National Park Service at the Santa Monica Mountains National Recreation Area. Taken collectively, my background, training, and the introductory interviews I had completed ahead of physically heading to Cherish sites cohered as a unique platform for participatory observation. One where my relative familiarity with the practices I was observing would enable me to follow more theoretical lines of thinking. As a descriptive exercise in its own right, the data generated through such observation would also serve to reflexively insert myself into the data produced, thus providing a means to contrast my own faculties of observation and deduction with the expository details provided by respondents (Gomm, Hammersley and Foster, 2000). Finally, the approach detailed in this chapter was also partially centred on engaging directly with the data being visualised. Often this would manifest in attempts to recreate specific visualisations myself, using both the prescribed protocol and softwares used by respondents. Additionally, in an attempt to further trace the translation or inscription of observed field and laboratory practice within such data, these experiments were further complemented by interrogating the metadata files attached to both visual and locative datasets.

The following chapter is organized in the following way. It will begin by first addressing the challenge or difficulty of developing a research methodology influenced by the theoretical orientations introduced in the preceding chapter. From there it will discuss the issue of *case study selection*: its justification, consequences, problems, or blindspots. It will then pivot to individual accounts of the practical methods pursued. Here it will address the use of semi-structured interviews, participant observation, digital data analysis, and photography I employed in the field. It will then focus on how the data generated through these methods were analysed, specifically the software used to such ends; namely, Nvivo (the programme through which both field notes and interview transcripts were processed) and

Agisoft Metashape (the primary photogrammetry software used by Cherish, which I used to interrogate the digital data my respondents shared directly with me). Finally, the chapter will discuss the ethical challenges and issues posed by the organisation and execution of the fieldwork described below.

3.2 Bridging theory to method

Digital objects are mutable and mobile and therefore require particular methodological approaches. Contemporary geographical scholarship, for example, has seen such adjustments articulated in methodologies specifically attending to the travelling of digital media across both interfaces and networks as they are modified and cohere into discrete visual products (Bates et al., 2016; Crang, 2015; Degen, Rose, and Melhuish, 2015; Lury and Wakeford, 2012; Melhuish, Degen, and Rose, 2016; Rose, Degen, and Melhuish, 2014; Rose, 2016a). While not an ethnography in the traditional sense of the term, the methodological approaches employed for my research are influenced by the tradition of *multi-sited ethnographies* as a means of attending to the transitory or mobile nature of data and the digital objects they can compose. As addressed in the previous chapter, this thesis takes *assemblage, situation, intra-action,* and *circulating reference* as its operative terms for addressing the dispersed and iterative nature of the production of digital objects. As a result, the methodological approach detailed here hinged upon the framing of Cherish data, the Cherish workflow, and the data objects they eventually come to comprise, as all being both mobile and distributed (Rose, 2011; Rose, 2016a; Rose, 2016b; Hannerz, 2003; McFarlane, 2009; McFarlane 2011).

Data and digital/data objects can refer to a great many things, from the analytics generated by social media platforms like Twitter, to the individual images used to generate 3D models of heritage sites and features. As such, how data were discussed in the field with my respondents required careful consideration. This research focuses on data and digital

objects within relatively small networks and configurations, particularly when contrasted with ever-prevalent discussions of "big data" taken up elsewhere (Carter, 2018; Kitchin, 2014a; Pickren, 2018). Furthermore, it seeks to explore the inherent socio-materiality of data, actively resisting any tendency to consider data in either objective or neutral terms (Bates et al., 2016; Camus and Vinck, 2019; Kitchin, 2014b; Ribes, 2019). In tracing the cohesion of data objects across sites of production, the context or application associated with a given site or procedure changes how data should be considered (i.e., how data come to be relationally defined by contexts of situation, process, and assemblage). Part of this is bound up in the extent to which data can alternately be defined as reference-based or statistical information, as “specimens”, or as both (Ribes, 2019). The data and digital objects addressed in this thesis are described (both by myself and by my respondents) in their capacity to document and reliably describe dynamic heritage sites and features in states of collapse and erosion. In this sense, data are described as specimens of a sort. Yet they are also described in their capacity to function as critical pieces of referential information defined by the task or application to which they are put. As such, all of my field methods ─ from interviews to visual data analysis ─ were performed with the multiple valences of data in mind, with questions about sites, context, and situation informing what to observe, what to ask, when, and *where*.

My fieldwork has sought to account for the site-specific and situated nature of observed activities both within the context of the assemblages they comprise at specific sites of activity, and within the larger multi-sited workflows in which they are also situated. It traces these assemblages by following Cherish data from its initial acquisition to its eventual coherence as digital objects. In so doing it illustrates not only how the situated circumstances inherent to individual sites of activity become inscribed in the data produced, but how these inscriptions are translated as the data moves throughout a standardised workflow. To conceptualise both the established valency of heritage data *and* its distribution and mobility, I

refined my methodological approaches by consulting a broad survey of literatures on multi-sited ethnographies (Coleman and Hellerman, 2011; Falzon, 2009; Gustavson and Cytrynbaum, 2003; Marcus, 1998; Marcus, 2011; Ryzewski, 2012; Tsing, 2005; Tsing 2017). Here, the work of Anna Tsing proved particularly instructive. Not only does Tsing's use of multi-sited ethnographies reveal how relationships between the 'local' or 'particular' and the 'networked' or 'distributed' co-produce one another, but how the *travel* between both can be utilised as the "ethnographic object" to describe their co-production (Tsing, 2005, pg. 7). Furthermore, Tsing's specific attendance to "the sticky materiality of practical encounters" as a means to describe such ethnographic objects further helped to develop the empirical means for exploring theoretical concepts like *intra-action* or *circulating reference* (Tsing, 2005, pg. 1). As such, my fieldwork not only targeted site-specific encounters between practitioners, heritage sites, technologies, and data, but further focused on that which *emerges* from these encounters (i.e., emergent datasets, sites, and situations). In following what emerged from these productive interchanges across multiple sites of activity, it also located the means necessary to trace the relationships between particular, local, or site-specific centres of activity distributed across the larger Cherish workflow. Finally, in comparing the derivation of data and digital objects from multiple projects within the Cherish scheme, travelling with this data between sites of production further helped to trace the *territorialising* and *coded* aspects of the Cherish workflow overall. Accounting for the distribution of standardised components such as equipment, file formats, metadata, and methodological protocol, for example, helped me to decipher how the Cherish project maintains standards like resolution and accuracy for its outputs despite the contingencies defining the situated enactment of such work.

Because this thesis describes the production of Cherish data in terms of either site-specific assemblages and performed material engagements, the chosen methodologies were

also selected in order to address how site distribution and situated performance either facilitate or complicate the production of *digital* archaeological knowledges. In the project of practically considering/querying these processes, then, the enactment of my chosen methods was again informed by Bruno Latour's notion of *circulating reference* (1999). *Circulating reference* portrays the abstraction of knowledge as a dense process wherein laboratories and field sites can fluidly permeate and become one another. "Reference", therefore, becomes another operative word in understanding the development of digital visual objects, articulated by Latour as a means for "keeping something constant through a series of transformations" (Latour, 1999, pg. 58). As with the larger body of Actor Network Theory scholarship, the underlying implication is that the cohesion of any object—be it a machine, a digital model, or scientific axiom—is reliant upon the cohesion of an underlying network (Latour 1999; Law, 2001; Law & Mol, 2002). Specifically as it pertains to practices like 3D modelling—where the very basis and functionality of the work is predicated on the circulation of data (and metadata)—the performance of my methods was here enacted in order to most effectively trace the systems of "reference" that translate physical heritage sites into digital objects.

3.3 The Cherish Project as a Case Study

The decision to centre my fieldwork on the Cherish project resulted from a number of factors. Not only was the timing incredibly fortuitous (when I initially reached out to Anthony Corns, for example, they had just begun to send investigators into the field to conduct surveys at chosen sites), but the methodological toolkit they would be practicing in the field was dynamic and varied. In short, because the Cherish Project employs a comprehensive approach to the digital survey and visualisation resulting in a diverse output of data and visual products, I had the opportunity to produce varied datasets of my own based on the observation of such work.

Case study research has long been criticised on the basis of its relative inefficiency for producing findings that can be extrapolated into more broad or generalised findings. Its strengths, however, lie in the analytical or theoretical purchase of the empirics it can and does have the capacity to generate (Gomm, Hammersley, and Foster, 2000). This is further compounded by what many have identified as the effectiveness of "intensive" research approaches; i.e., observational and description-based inquiries centred on the immersion of the social scientist within a field of study. It is Paul Connelly's contention, for example, that the "primary goal of ethnographic studies is to discover the causal relationships operating in the case studied, rather than to test whether these relationships occur elsewhere" (Gomm, Hammersley, and Foster, 2000 pg. 236). It was through an "intensive" approach to my case study — via travelling with the iterative development of the data produced — that I aimed to trace both the multi-sited *and* situated nature of Cherish work. Given how this research is grounded in the contention that archaeological knowledges are assembled, situated, and socio-materially constructed, it necessarily follows that such knowledge producing activities be defined by the particularities of their respective situational or circumstantial compositions. As such, something like a broad survey of digital archaeological initiatives across numerous countries, for example, wouldn't be necessary to pursue the core aims of my research. On the contrary, what was required was the intimacy and access my collaboration with the Cherish Project ultimately provided.

Defining my case study, however, also required being able to reflexively situate myself within it. Simply by virtue of being permitted to follow Cherish investigators, observe and assist them in their tasks, and to intermittently interview them, the nature of the work I would observe and analyse would be changed by my very participation (Katz, 1994). As a researcher partially inserted into their workflow, I directly participated in the construction of my own case study, rendering it a methodological device for pursuing the central questions of my research. As such, because this thesis focuses on the production of archaeological

knowledges via the enactment of specific methodologies, the knowledge produced through *this* thesis has been produced both by how *my* methods were enacted as well as my being embedded within a knowledge producing practice like the Cherish Project.

As a case study, the Cherish Project also enabled me to produce datasets more than sufficient for my own analysis. Not only was I able to observe many of their prescribed methods in action across numerous field sites, but I was further given access to any and all of the data I observed being produced[22]. In order to best pursue my central research question of *how digital archaeological knowledges become constituted,* my fieldwork needed to trace the enactment of as many visualisation methods and the production of as many different outputs as possible. Furthermore, because this research specifically targets the *site-specific* and *situated* assembling of tools and expertise within a given process or method, the careful and finely grained observation of each individual modelling or survey project was uniquely important and valuable for my aims. Finally, the inherent multi-sitedness of the Cherish Project — both in the distribution of its research areas across Wales and Ireland *and* the travel between field and office sites which their work necessitates — further enabled me to explore key questions about the mobility and translation of data as they are derived and processed. Taken together, the Cherish Project offered the opportunity to undertake my own situated observation of a range of practitioners each with their own areas of expertise, pursuing numerous methods of digital visualisation at a diverse selection of heritage sites. Considering my involvement with Cherish began with a cold call to Anthony Corns after browsing their collection of models on Sketchfab.com, our collaboration ultimately developed into something close to ideal.

[22] Although it has yet to be collected or made available through a public data portal, all the data produced by the Cherish Project will eventually be open access. At the time of this writing, Cherish Practitioners had shared some 130GB of raw and processed data produced through their practice.

3.4 Cherish Methods

Before addressing the methods I enacted in the field, it is necessary to detail and introduce both the methodologies I was observing, as well as the practitioners I was following. Within their funding charter and executive summary (drafted in 2016), the Cherish Project outlines nine initiatives, most of which are presented as resolving in nine key deliverables (*see appendix I)*. Of the nine, this thesis is principally concerned with the following four:

I. *CHERISH survey teams developing joint best-practice guidance*: Integrated joint-nation teams deployed to survey and record heritage sites threatened by climate change in targeted coastal communities, using the latest innovative technologies and remote sensing techniques.

II. *CHERISH permanent network of 'local change' fixed survey markers and indicator wrecks:* A key legacy of the operation, CHERISH will provide the first 3D baseline fixed survey points and data for selected heritage assets specifically aimed at future monitoring of climate change.

V. *CHERISH 3D reefs, islands and headlands—seamless onshore/offshore 3D models:* A number of innovative digital 'real maps' derived from LiDAR and photogrammetry which will provide 3D data geomatic data for planning
and management.

VIII. *CHERISH open access shared web portal:* A key tool of CHERISH for information delivery and awareness-raising and an important legacy of the operation for future adaptation strategies (Cherish Charter, 2016).

The methodologies implemented across these initiatives are many, with each individual approach suited to the context and specificity of both the sites being surveyed and the objectives being pursued. These range from aerial photography (a method principally used for prospection) to a bevy of remote sensing techniques (primarily used in surveying and modelling). Given that this thesis focuses on the survey and modelling teams from both Discovery Programme and the RCAHMW, my fieldwork primarily centred on the observation of the methods used in the repeated monitoring and modelling of chosen sites. Following the methods Cherish practitioners regularly repeated not only meant attending to the projects for which they had acquired (and were still acquiring) the most data, but further meant that both their approaches to visualisation and their outputs could be effectively

contrasted and compared against one another.

The first of these is *Unmanned Aerial Vehicle (UAV) survey*, also known as *drone survey*. UAV survey results in the production of two distinct sets of data: one coordinate-based, the other visual. The coordinate-based data is produced by using precisely calibrated GPS antennas to register spatial coordinates for strategically placed location markers within a field of survey. These measurements are eventually processed with the visual datasets in order to geo-rectify the images taken form the drone. UAV survey photographs identified sites and features via the use of drone-mounted digital cameras. These images are later processed together via a method known as "photogrammetry". Photogrammetry matches the individual images within the collective set to identify shared features across multiple images. These similarities are then abstracted as "points" which — because of the coordinate-based dataset affiliated with this visual information *and* the GPS coordinates generated by the drone itself — come attached with individual spatial coordinates via their individual metadata records. At a certain stage of the process the photographs are removed from the model, leaving just the points derived from the pixel matching. These points constitute "clouds" which can eventually be re-configured as polygonal surfaces and later processed as 3D models (*figures 3.1 — 3.5*). The Discovery Programme acquires its coordinate-based datasets using a Trimble GPS antenna, which synchronises with a proprietary software known as Trimble RealWorks. The RCAHMW, by contrast acquires its spatial data via a technically similar system manufactured by Leica. Both use DJI Phantom IV Pro copter mounted drones, a durable and dynamic UAV used by both professionals and hobbyists. Furthermore, both Discovery and the RCAHMW use Agisoft Photoscan[23] as a photogrammetry processing software.

[23] Which has since been re-branded by Agisoft as "Metashape" but is still commonly referred in the industry as Photoscan.



Figure 3.1. *This series of photos (above) are several from a stereoscopic collection of images taken of the King's Stone located in the Cotswolds. This collection of images (23 in total) was submitted and aligned within the Photoscan software where, when processed against each other, a* ***sparse cloud*** *was produced.*

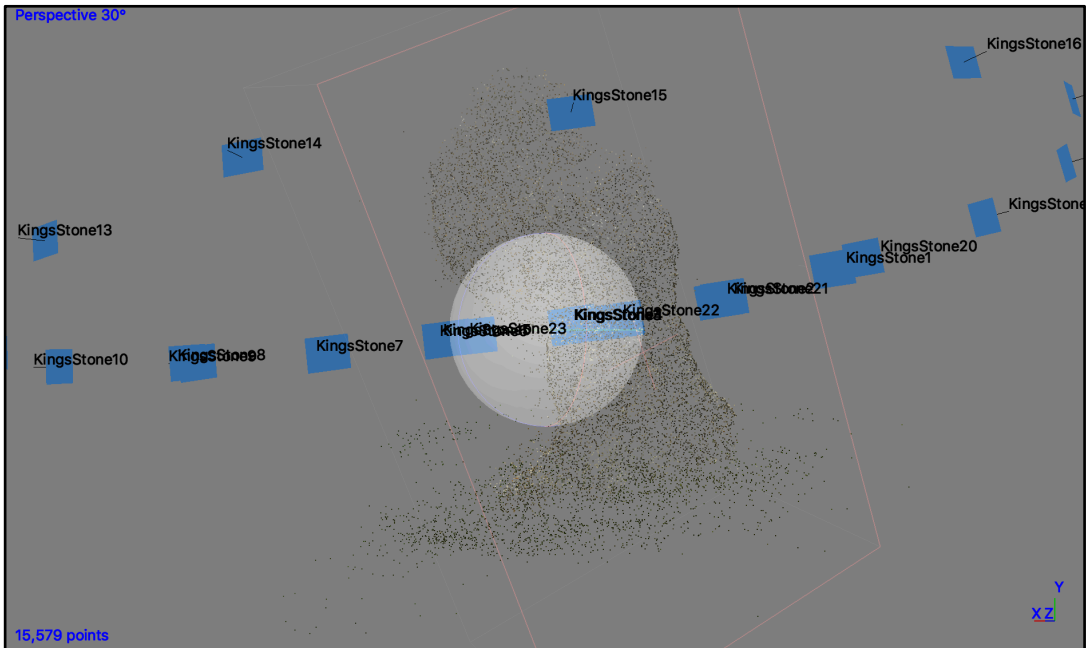


Figure 3.2. *In this sparse cloud the blue tiles represent each of the individual photos, the hazy cluster of coloured points in the middle indicate shared features across all the images the software has located and placed. As you can see in the bottom left-hand corner of the bottom figure, this sparse cloud is composed of 15,579 individual points. Source: photos and model produced by author.*

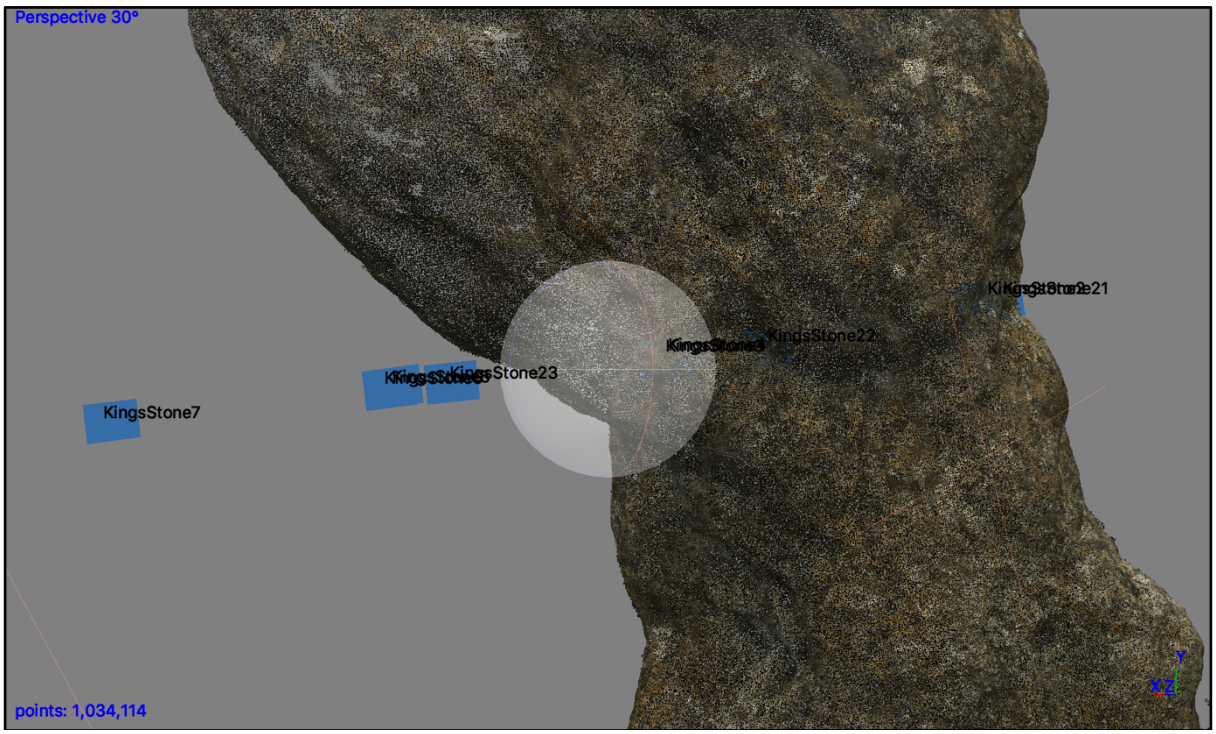


Figure 3.3. *A screen grab of the* ***dense point cloud*** *generated from both the original images (figure 3.1) and the sparse cloud produced in the preceding stage (figure 3.2). Here new points are derived using both of the sparse cloud and the original images, resulting in a semi-cohesive form composed of 1,034,114 individual points.*

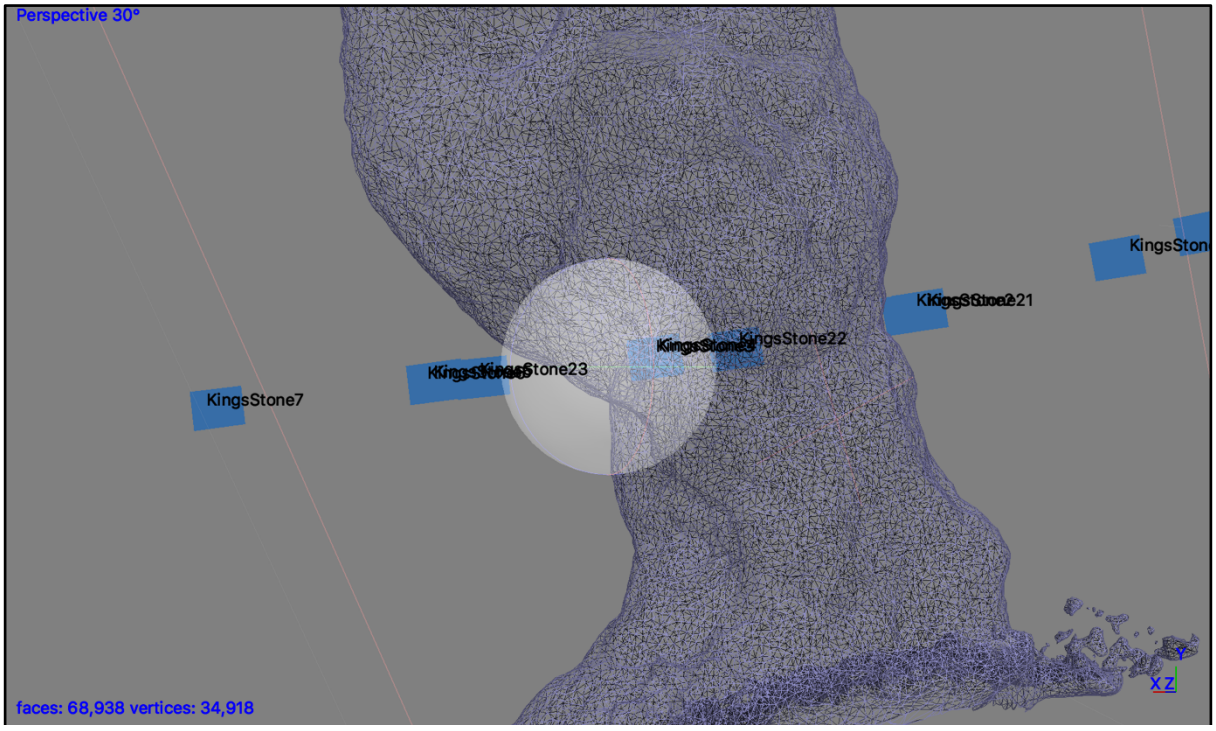


Figure 3.4. *Here the dense cloud above has been processed by the software to produce a* ***wire frame mesh****. Here selected points are re-visualised as vertices to render the dense cloud as a cohesive surface. As indicated in the bottom left-hand corner of the bottom image, the wire frame mesh is composed of 34,918 vertices, which when connected results in 68,938 polygonal "faces". These numbers can be either elaborated or simplified based on how thoroughly the process of mesh production has been calibrated to operate. Source: models made by author.*

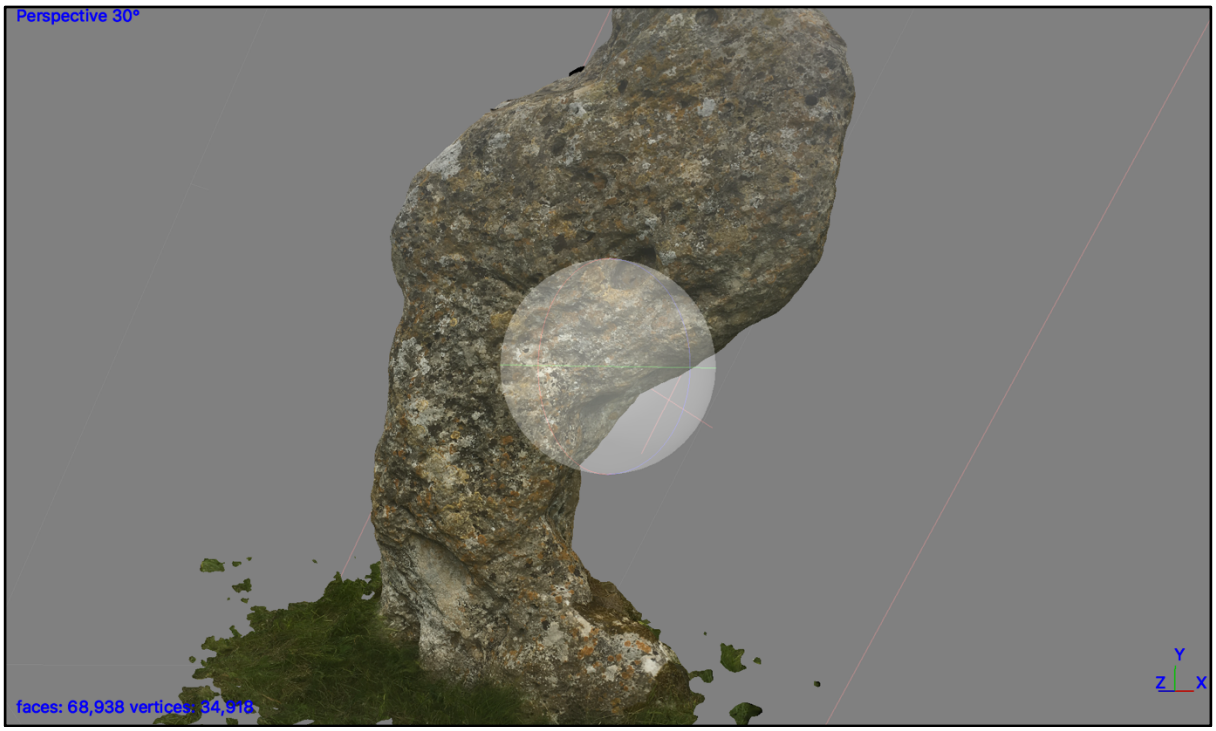


Figure 3.5. *The above is a completed model of the King's Stone. Here the original imagery is again inputted in order to derive what is known as the "texture" for the model. This textured imagery is applied to the mesh to produce a surface which approximates the geometric complexity of the surveyed feature while reducing the overall count of points and data of the resulting model. As such it becomes much easier to share across platforms with prescribed file size limits, such as sketchfab.com, etc. Source: model by author.*

The second method of note here is laser scanning. Laser scanners directly produce point-based clouds. The majority of laser scanners are further differentiated by whether they produce points through "time-based" or "phase-based" scanning. With time-based scanners the locations of scanned points are derived by determining the time it takes for an emitted laser to leave the scanner and return to its internal sensor. With phase-based scanners, point locations are derived by deciphering the interference, or "back scatter", of the continually emitted and reflected signals lasers (Lillesand, 2004). Both the Discovery Programme and the RCAHMW use phase-based scanners manufactured by the Faro company. These instruments sync with a proprietary software called "FaroScene". A typical scan job is composed of 4-6 scans taken around the circumference of a site or feature. These individual scans are stitched together by registering the location of stable or fixed objects (usually globe-like spheres, dispersed across a site before scanning) which are visible across all the individual scans. Like UAV survey, laser scanning is further predicated on the parallel derivation of coordinate-based data, which is in turn attached to these globe-like targets via the same GPS antenna's either group would use in the field. Once scanned clouds are made cohesive, they are than ported over to Agisoft Photoscan to be further processed as 3D models (*figure 3.6*).

The final method observed for this thesis was analytic walkover earthwork survey (also known as GNSS survey), a method only undertaken by the RCAHMW. In a GNSS survey, practitioners rove heritage landscapes with GPS antennas, taking periodic measurements of the eastings, northings, and elevation for anthropogenic earthworks like berms, entryways, and mounds. Depending on the size of the site, walkover survey can produce anywhere from hundreds to thousands of individual measurements. The result is something like a rudimentary two-dimensional point-cloud which practitioners eventually use as the basis to render what are known as "hachure" plans. It is an interpretive method

primarily used in order to decipher the "phasing"[24] of archaeological sites (*figures 3.7 and 3.8*).

Across all the methods observed, the accuracy of geo-spatial measurements proves foundational. Regardless of how the outputs are applied or used, the "value" of these visualisations is almost always bound up in the accuracy of their respective geo-referencing. As such, one of the central questions my fieldwork has asked is how the primary acquisition and subsequent distribution of these measurements spatialise heritage sites and features, both in the field and in the context of digital visualisation softwares.

[24] The process through which field archaeologists untangle the palimpsest of given site's continued habitation across centuries.



Figure 3.6. *An oblique view of Ferriter's Castle, a monumental feature of interest located on a promontory in Co. Kerry. This image was produced using laser scanning and was derived from six individual scans taken around the walled feature visible at the top centre of the image. At this stage, scanning projects look remarkably similar to the dense clouds produced in photogrammetry; although they have been derived from 6 input scans, rather than the hundreds of photos commonly used to produce photogrammetric models. The above image is a screen grab of this project in progress as it was being worked on in the Trimble Real Works software. From here it will be ported over to other visualising softwares to render it as a cohesive surface and model. Source: screen grab taken by Robert Shaw.*

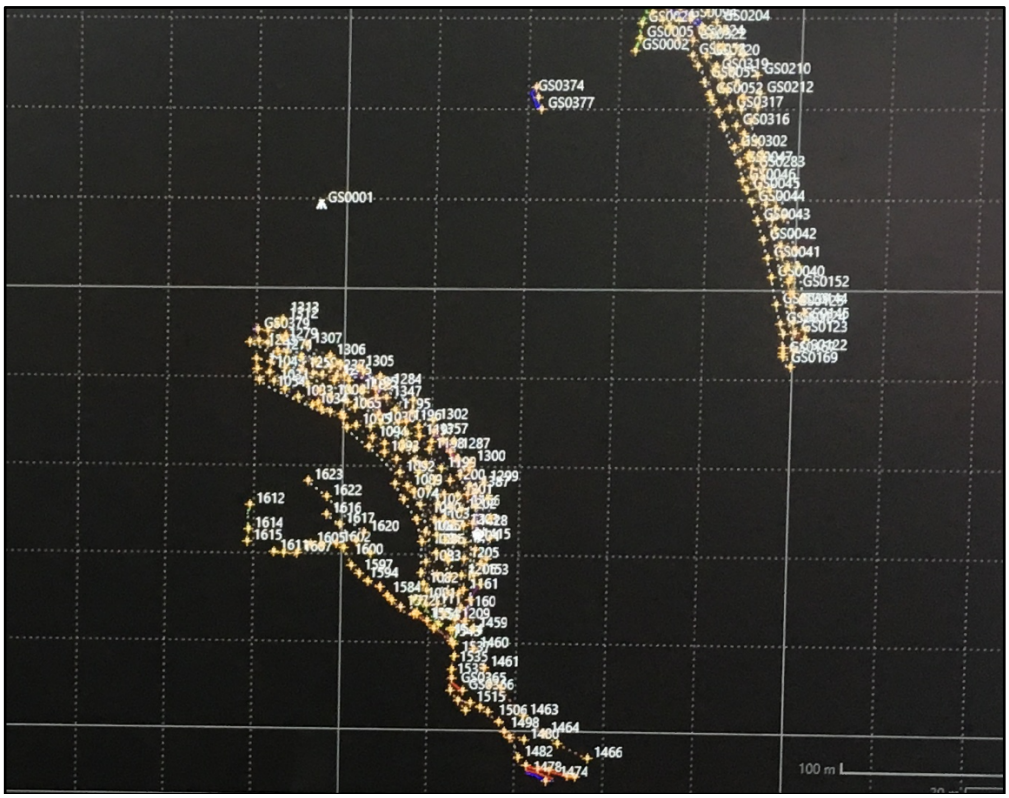


Figure 3.7. *A screen grab of coordinates produced through GNSS survey at Castell Bach in Ceredigion, Wales. Each point represents as place in or around the anthropogenic earthworks located at the site, each with unique spatial coordinates. The plans are printed off taken back into the field where practitioners draw up "hachure plans" by hand.*

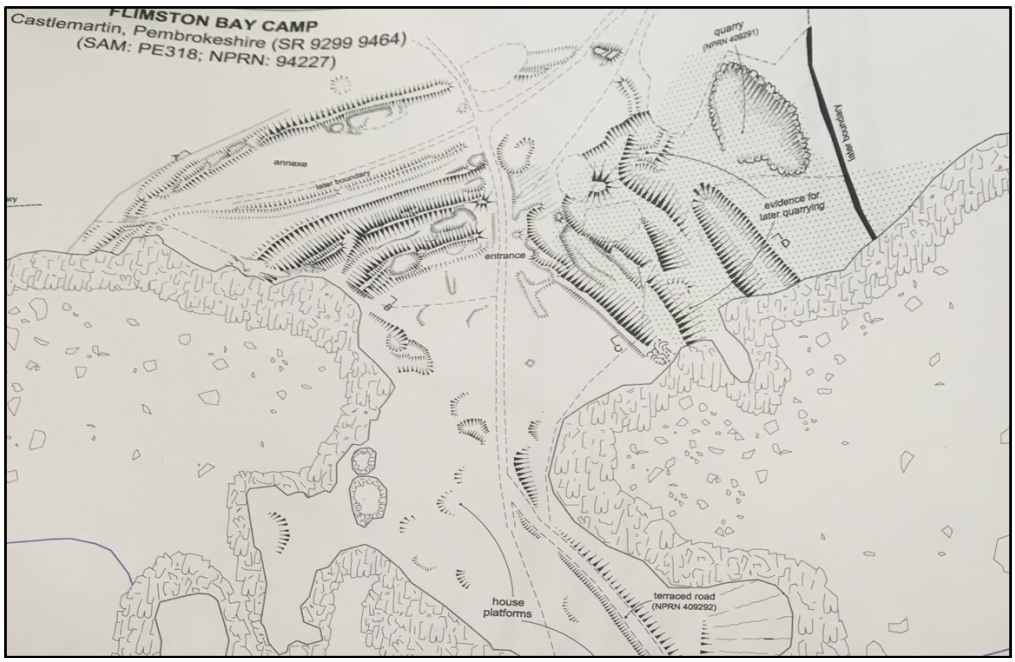


Figure 3.8. *A hachure plan of a Cherish site located in Pembrokeshire wales. Using a plan like the one visualised above, practitioners interpret earthworks to determine and estimate questions about land use and site construction, i.e., how the inhabitants of archaeological sites used and lived in such spaces. Source: screen grab and drawing both produced by Louise Barker.*

3.5 Cherish Personnel

While Cherish employs numerous individuals across the four assembled partners (in capacities ranging from administrative and managerial to field-based), I chose respondents based on their specific involvement in the methodologies I planned to observe. All of my respondents granted permission to have their full names used within this thesis, as well as their photographs taken throughout my field work (as per the written consent forms compliant with Oxford's CUREC protocol). At the conclusion of my fieldwork, I had worked with a total of eight Cherish investigators:

— **Chief technology manager and lead Cherish investigator, Anthony Corns** (*Discovery Programme*): Anthony has worked as the chief technology officer for Discovery for nearly 17 years. He is also one of the original authors of Cherish's original funding charter and oversees much of the work being done in Ireland. While Anthony occasionally participates in Cherish fieldwork, he is primarily based in the Dublin offices.

— **Senior geo-surveyor, Robert Shaw** (*Discovery Programme*): Robert is principally charged with executing all UAV and laser scanning projects within the Irish Cherish study areas. Robert not only conducts the necessary in-the-field survey work, but also processes and visualises most of the data he acquires. Some of these visualisations end up as what this thesis will describe as *terminal translations*, i.e., a visualisation that has been worked-up to a point of having applicative use. Other versions of Robert's visualisations are passed along for more advanced modelling.

— **3D modeller and graphic artist, Aaron Deevy** (*Discovery Programme*): Aaron's participation in Cherish is primarily centred on generating models for public consumption. Aaron receives partially visualised datasets from the surveys Robert acquires and processes

and is often tasked with reconfiguring such datasets in order for them to function efficiently on specific servers and platforms. Often this concerns reducing the size of a given project or model by way of reconfiguring its geometry and surfaces.

— **Field archaeologist, Sandra Henry** (*Discovery Programme*): Sandra has a background in maritime archaeology and is one several employees Discovery hired specifically to work on Cherish. As a field archaeologist, Sandra is primarily tasked with site prospection, identification, and interpretation. Like all Cherish investigators, Sandra is also involved in the logistical duties associated with field work, such as securing permissions from local landowners.

— **Field archaeologist, Edward Pollard** (*Discovery Programme*): Like Sandra, Edward is another of the field archaeologists brought into the Discovery Programme at the outset of the project. Also like Sandra, Edward has a specialisation in Marine archaeology.

— **Aerial photographer and Cherish lead, Toby Driver** (*RCAHMW*): Toby has been the aerial photographer for the RCAHMW since the late 1990s and, along with Anthony Corns and Louise Barker, is one of the original authors of the Cherish charter and funding application. In his capacity as an aerial photographer, Toby works in site prospection and identification and, as of spring 2019, also participates in UAV survey at Cherish sites.

— **Senior field archaeologist, Louise Barker** (*RCAHMW*): Louise is the senior field archaeologist for the Royal Commission and, as mentioned above, one of the original project authors for Cherish. Within the context of the project overall, Louise is unique for her work analytic walkover survey, the data for which she is principally responsible for acquiring and processing. Like other investigators, Louise also participates in other facets of the project; from UAV survey to field logistics.

— **Lead Cherish investigator, Daniel Hunt** (*RCAHMW*): Daniel was hired by the RCAHMW to work as the commission's principal Cherish investigator (meaning he does not work on any other commission projects). As such, he is simultaneously responsible for UAV survey, laser scanning, and assisting Louise in walkover survey projects (and their subsequent visualisation as hachure drawings). Furthermore, Daniel also handles the processing and visualisation of all data acquired through UAV and laser scanning survey.

3.6 Cherish sites

I travelled between Ireland and Wales from November 2018 to August of 2019, making routine trips to the Discovery Programme home offices in Dublin, the RCAHMW's home offices in Aberystwyth, and to numerous Cherish study areas in both countries.

— **November 2018**: The first of these excursions was centred on conducting entrance interviews with key personnel at the Discovery programme in Dublin. It was here that I first interviewed Anthony, Robert, Aaron, and Edward. Our conversations ranged from discussions about key equipment to field methods being employed by Cherish. Each respondent provided detailed overviews of both their respective background and their participation in the project. My conversations with Anthony were centred on a 200-slide presentation detailing both the history of the Discovery Programme and the evolution of their technology-based innovations.

— **March 2019**: Much like my November trip to Dublin, my first trip to Wales began with a visit to the commission headquarters in Aberystwyth to develop profiles of the Cherish team there. Daniel, Toby, and Louise each sat for extended entrance interviews covering their backgrounds and participation in Cherish. This trip also included my first site visit, wherein I observed Daniel and Louise conducting walkover earthwork survey at *Castell Bach*, an Iron

Age promontory fort located on Cardigan bay. The following afternoon I returned to the offices in Aberystwyth to observe the initial processing of the data I had observed being acquired, as well as an initial walk-through of Daniel's ongoing work rendering and visualising models from earlier surveys.

— **April 2019**: Here I travelled to Co. Kerry with Robert, Edward, and Sandra to observe Discovery's field work at several sites. Our activities included observing UAV survey at both *Dunbeg Fort* and *Dun an Oir*, site prospection at *Gort Nagan* and *Ferriter's Castle*, updated location mapping for an unstable shipwreck site at *Rossbeigh Strand*, and submarine UAV testing at *Vantry* harbour. As alluded to in Chapter 1, the weather was unfortunately unpredictable for the majority of this visit and, as a result, we were unable to complete the planned laser scanning.

— **May 2019**: Here I returned to the Discovery offices in Dublin for two reasons: to observe the processing and visualisation of the UAV datasets I had observed being acquired in Co. Kerry and to observe a supplementary demonstration of laser scanning protocol, given we were unable to perform any such tasks in the field. We not only conducted laser scans of the Discovery library, but began the process of working these scans into models. To elaborate these explanations, past scanning projects were replicated for my benefit. These activities were almost entirely the responsibility of Robert Shaw.

— **June 2019**: Returning to Wales, I travelled with Daniel, Toby, and Louise to the Pembrokeshire coast. Here we conducted UAV survey at *Nab Head* and hachure drawing at *Carfai Bay* (which were based on walkover survey conducted on the previous visit) before returning to Aberystwyth to observe the secondary stages of visualisation on these datasets.

— **August 2019**: For my last field visit I again travelled to Wales, this time to *Dinas Dinlle,* a flagship study area for the Welsh contributions to Cherish. Dinas, like Dunbeg, has been repeatedly monitored and modelled (through numerous methods, including UAV) since the project's inception. On this visit, however, the RCAHMW's Cherish team — in conjunction with the Gwynedd archaeological trust — staged a full-scale excavation of the site over a two-week period. As such, this visit served as something of a logical end point to my fieldwork, given that excavation can serve as one of the terminal resolutions for Cherish initiatives. Outside of the digging, my time at Dinas was also centred around a community outreach day, when a 3D printed scale model of the site (produced from UAV survey data) was unveiled for the public.

3.7 Field methods: Interviews

Travelling between Wales, Ireland, and the United Kingdom, my fieldwork was centred on three primary research methodologies: interviews, participant observation, and visual data analysis. Interviews were conducted throughout the entirety of my fieldwork across a number of locations and sites. In many respects my approach to interviewing my respondents could be discussed as semi-structured, in that I didn't enter an interview with a script or hard list of topics I wanted to touch upon. On the contrary, they were consistently pitched in such a way as to ensure that discussions would develop organically and — as the project progressed — became increasingly centred on the active processing or handling of Cherish data. As both my relationships to my respondents and my knowledge of Cherish activity evolved, so did the nature and dynamic of these conversations. The initial trips to either Dublin or Aberystwyth, for example, were organised around entrance interviews. Here, each of the individual respondents volunteered background about both their personal history and experience, as well as their unique placement within the Cherish workflow. These interviews proved particularly helpful in sketching a larger picture of the Cherish Project as a whole; both its methods, sites,

and technologies *as well as* the organising principles of territorialisation and/or coding that held them together. Moreover, they evidenced how the individual respondents saw themselves fitting into these assemblages. Because these conversations were not structured around processes or activities I had already observed, the respondents frequently used examples of past work as a means to illustrate their specific role in the Cherish Project. These conversations were also semi-structured, often emerging through the specific discussion of the examples each practitioner brought to the table. Anthony Corns, for example, used PowerPoint presentations from talks he had already given on Cherish to familiarise me with the particulars of their work. My entrance interviews with Daniel Hunt, by comparison, moved between his desk and the RCAHMW conference room in order for him to be able to pull up previous models and figures as necessary. Collectively, these interviews signposted what I should expect to encounter once in the field. As such, they were instrumental in helping me prepare for both the interviews I would conduct at later dates and participant observation I could expect to perform once embedded in the field.

As the project developed into subsequent visits, however, my interviews became increasingly centred on site-specific practices and tasks, almost like desk-based "walk along" interviews. Particularly as it pertained to observed activities of data processing and visualisation (see Chapter 5), my interviews became focused on both the explanation *and* enactment of such tasks, effectively illuminating specific complexities and contours that would have otherwise remained inaccessible within a more standardly formatted interview (Pink, 2007). In these situations, however, because the "site" of the interview and the "site" of performed Cherish work became effectively elided, the dynamic between myself as an interviewer and my respondents as interviewees likewise shifted in meaningful ways. Rather than have the conversation structured solely around an exchange of questions and explanations, in having both myself and the respondents engaged in a real-time task with

actual consequences, we would often collaborate and problem-solve together. As such, the adjusted dynamics engendered by the place or site of these specific interviews likewise resulted in a more collaborative production of the empirical data this thesis uses (Elwood and Martin, 2000).

These desk-based and task-focused interviews provided respondents opportunities to narrate their work as they did it. As a result, they were particularly effective at illuminating how their respective understandings of targeted heritage sites ― and their subsequent digitisation ― are shaped by the distinct configurational relationships between their own expertise, the instruments or tools assembled, and the mandated protocol they followed. Often these configurations would become most perceptible to me ― as the observer/interviewer ― as respondents would navigate snags or surprises when they occurred. It was often the act of untangling the friction between an expected result and an actual result together that necessitated a forensic diagnosis of what had occurred and why. Furthermore, this real-time evaluation of tasks and processes provided ample opportunity to consider the positionality, situation, or partiality that determined a practitioner's mediated involvement in both Cherish protocol and the data produced.

A substantial portion of these interviews also generated meaningful discussion around the articulation of *skill*; i.e., the tricks and crafts practitioners employ in their work both within and outside mandated protocol. To these ends, these interviews further teased out the reflexive impact specific visualising technologies and methods have on situated practice. As such, this discourse further illuminated the specific agency instruments and softwares have on both workflow and habit, and how the performance of given methodologies is articulated with the help of ― and occasionally, in spite of ― the agencies of such assembled softwares and tools (Suchman, 2006; Elwood, 2012; Vertisi, 2015; Woodward et al, 2015; McCollough, 1996). Attending to practitioners' understanding of their own tricks and skillsets helps to

further illuminate how the instruments and tools assembled in Cherish practice relate to one another; where they resonate together or where there are frictions that inhibit and frustrate specific workflows.

Finally, these interviews also revealed something of the *material* consequences of working with data in various contexts or at different sites, particularly as it pertains to the size and maneuverability of certain datasets. Because the movement and cohesion of Cherish data is predicated on a physical/material infrastructure (such the relationships between assembled hard wares like desktop computers and field instruments) as well as a digital one (such as the relationship between softwares), the desk/task-based interviews helped to illuminate what the limitations and/or affordances of either infrastructure (or the relationships between the two) might be. Engagements with Cherish data were here discussed as having distinct "material properties"; the capacity of a given process to crash certain platforms or machines, for example, or the relative compatibility between field instruments and desk-based workstations via the data shared between them. These discussions helped to further evidence the "mutability, persistence, robustness, spatiality, size, durability, flexibility, and mobility" of Cherish datasets and visualisations (Bates et al, 2016, pg. 3).

3.8 Field Methods: On-site participant observation

As helpful as it was to be able to conduct interviews in parallel with observed stages of production, it simply wasn't always possible. Processes of *data acquisition* by the Cherish team (see Chapter 4), for example, posed distinct challenges for interviews. Executed out of doors and operating under time constraints often imposed by either the limitations of weather or light, Cherish practitioners couldn't answer questions with the same detail and clarity while performing analytic walkover survey or drone survey. This is not to say that conversations did not take place while we were in the field, but that these conversations were

sporadic and often limited to brief, though illuminating, explanations. The data I generated at sites of acquisition, then, were produced through on-site participant observation, where I would closely follow my respondents as they went about their work, assisting when and where it was appropriate, and actively attempting to capture as much of what had occurred within detailed descriptive notes of my own. And while these notes would occasionally feed back into interviews at later stages, they primarily functioned as datasets with their own distinct value to the thesis and the analyses I would eventually perform. For one, the data generated through observation helped me to trace contours and connections that practitioners themselves might not see or think about in the same way. Where, in the context of an interview, I had to actively avoid not pushing conversations in directions that were too theoretical, I often heavily relied on theory to process my observations in the field.

The key distinction between my interviews and participant observation, then, is one of voice or authorship. Where the desk-based interviews resolved in robust conversation centred on a given process as it was being enacted, the description generated through participant observation served as a platform to directly explore theoretical questions within the context of Cherish's applied methodologies. And while it is also true that my time at these field sites was often spent assisting my respondents, the data generated through these engagements was not as collaborative as the data generated through the interviews at sites of processing/visualisation. The reflections captured in my field notes ─ even when they pertained to my participatory involvement in a given task ─ were ultimately filtered and processed through my faculties of observation and interpretation alone.

Much of this is also relevant to how the activities of either acquisition or processing were effectively being *demonstrated*. The activities central to the semi-structured interviews primarily provided respondents a means to *demonstrate* their approach to prescribed Cherish initiatives via a process of commentary and narration. To no small extent this was contingent

on the conditions afforded by the respective sites central to either acquisition or processing. In the office, for example, respondents were not working against time constraints or weather conditions. They had the time to consider my inquiries in direct correspondence to the work I was observing them enact. The activities central to my on-site observations, by contrast, were far less demonstrative; the work being observed served ─ first and foremost ─ to fulfill the duty or task at hand. As such, the descriptions generated at these sites and through these methods were defined by their capacities to derive theoretical inferences.

As such, these methodological approaches came to overlap nicely. My entrance interviews, for example, often helped to produce specific hypotheses that I eventually took with me to sites of acquisition, often guiding what I was observing. As mentioned above, the notes I would generate in field at sites of acquisition would also feed back into the content I would bring to task-based interviews at staged at sites of processing/visualisation. Where the data generated in an entrance interview provided insight into how Cherish practitioners viewed and understood their relationship to the assembled components of the workflow, the data generated through observation provided a crucial insight into how the execution of such work actually materialised. In travelling with a project from the office to the field and back again, there was often a direct and demonstrative resonance between the two. But sometimes there were distinct frictions between how respondents described their work and how it was executed. Furthermore, where the interviews provided insight into the situated nature of the prescribed methodologies or the partial objectivity of the respondents enacting such methods, the on-site observations were crucial to understanding both the mechanics and consequences of these methods once enacted.

As a *participant* at sites of acquisition, I would most often assist practitioners in very practical ways: helping to carry or assemble equipment, for example. It would be a gross overstatement to assume my participation directly impacted, or was inscribed within, the data

produced at such sites. Helping, even if only in minor ways, allowed me to observe the processes being undertaken by the Cherish team. Given how much of the observed activity at these sites centred on the photographic documentation of heritage landscapes (as well as the numerous preparatory steps leading up to flight and photography), there were several instances where I was asked to either take photographs myself, or to more actively assist in the execution of activities inherent to UAV survey (such as recording geolocative measurements produced in the initial stages of acquisition). As will become evident in the empirical chapters to follow, the execution of drone survey requires a type of visual engagement with interfaces and instruments that prohibits practitioners from watching the drone maneuvering in the sky. In such instances I was asked to keep a lookout, habitually notifying the pilot practitioner of where a drone might be physically located in relationship to a targeted headland. As such, it was through this specific type of participation that I was capable of grasping the distinct limitations and constraints resulting from *partial objectivity* produced by Cherish's protocols for UAV survey. Furthermore, the act of participation compensated for the fact that I was unable to conduct formal interviews on site. Simply put, what I could see or observe was often mediated by what I was willing to do, and what my respondents were willing to have me do.

3.9 Field Methods: Experiments with Cherish Data

Where the empirical data generated by both interviews and participant observation combine to provide a dynamic overview of how Cherish methods are assembled and enacted, there remained a need to investigate how the enactment or performance of prescribed methods comes to be inscribed in the resulting outputs as metadata. Simply put, interviews and participant observation are enormously helpful for querying *how* the data was produced, yet provided scant insight on the data itself. In order to pursue one of this thesis's central research

questions — namely, "*How does digital heritage data cohere into a digital object?*" — I needed to devise a means of analysing Cherish data on my own. Practitioners at both the Discovery Programme and the Royal Commission were remarkably generous in sharing the data I had observed them either acquire or process[25]. By May of 2019, in fact, I had compiled a cache of raw images, coordinate tables, point clouds, meshes, and more totaling around 130GB of disk space. As such, where the empirics generated through interviews and participant observation both traced the configuration of workflow assemblages and located the site-specific material engagements embedded within them, directly analysing the Cherish data provided the necessary means to understand in part how Cherish *objects* came to cohere, and which of these processes constituted them as formalised objects.

I pursued this in two ways. First, having downloaded Agisoft Photoscan on my personal laptop, I was able to replicate many of the prescribed approaches to image processing and visualisation laid out within the Cherish guide to photogrammetry (see appendix II). Replicating these procedures (the majority of which were undertaken during the desk/task-based interviews detailed above) provided an opportunity to supplement and problematise the empirics generated through site-specific interviews. Much as my experience performing participant observation at sites of acquisition afforded the opportunity to inflect theoretical questions or reasoning into my fieldwork, retracing the steps observed at sites of processing/visualisation enabled me to elaborate the data produced through my interviews in similar ways. At a desk-based interview, for example, the conversation largely concerned the mechanics of executing modelling protocol at sites of processing. In replicating these procedures on my own I was able to more carefully trace the provenance of the datasets being modelled to those I had observed being acquired. As such, I was better able to analyse these

[25] All of which, by virtue of the original Cherish Charter, is classified under creative commons licensure and open source. See section on ethics below for further explanation.

datasets in relation to theoretical concepts of translation, cohesion, and how visualisation protocol spatialised heritage sites within new digital contexts. This served not only to enrich a pre-existing dataset, but also to carry over key insights into the consideration of digital objects my analyses would ultimately resolve in.

Second, I also spent time analysing the individual files comprising the larger datasets used for photogrammetry. This meant accessing the metadata embedded within the images, clouds, and coordinate tables themselves. Metadata, it should be restated, are the *data about data* that Yuk Hui describes as one of the principal formalising agents in the cohesion of digital objects (Hui, 2016). Depending on the data type (image, cloud, etc.), this could be achieved in different ways. Individual images, for example, were processed using EXIF tools[26], producing multi-page documents detailing time-stamps, geo-tags, or the instrument data (camera model's, for example) embedded in each file. For point clouds or meshes, this meant querying processing softwares (such as Agisoft Photoscan) to produce work-logs and code scripts of their internal functions. Part of this was about lifting the lid of black boxes; finding the means to ask a specific data type or software to reveal something about itself that was not immediately evident. In a larger sense, however, this was more about the data. What of the work I had observed in the field or in the office had come to be inscribed in an image's metadata? What was noticeably absent? What was the consequence of reading these metadata files together in sequence? Working through the hundreds of images in a given photogrammetry project folder, this approach was informed by the well-established visual method of *content analysis*. Yet where content analysis (as a visual method) would normally be structured around identifying and analysing the visual languages and symbols inherent to the subjects or topics of a given photograph or film, my approach sought to trace connections

[26] A command-line application for reading metadata. For my experiments I used the following free EXIF Tool; https://exiftool.org/.See glossary for further detail.

between the metadata of drone imagery and situated circumstance of their acquisition. Here, I was attending to details like the time stamps embedded in images, or whether they had been captured during orthogonal or oblique photography missions (more on this in Chapter 4). Doing so enabled me to account for what specific processes of the observed UAV surveys came to constitute the resulting point clouds, or whether specific aspects of an acquisition project defined the resulting models more than others (Rose, 2011).

3.10 Field Methods: Photographs and figures

I took hundreds of photographs of my own while conducting fieldwork. During the entrance interviews in Dublin and Wales, for example, I made sure to snap pictures of each piece of equipment as it was unboxed and explained. While observing UAV survey, laser scanning, and GNSS walkover survey I took photographs every time a new step or was introduced and enacted; documenting how practitioners moved within a site of survey, for example, or how they configured their instruments and tools on-site. Rather than take photos at sites of processing, by contrast, I asked my respondents to generate screen grabs of whatever we were discussing on the screen (which they were always happy to do). And while these images did not necessarily resolve in a dataset I directly analysed, they were instrumental during the analysis of both my interview transcripts and field notes. Not only would a corresponding image help to illustrate a recorded conversation and jog my memory on something I taken down in my notebook, but they further serve as crucial illustration tools within the chapters of this thesis.

3.11 Challenges

Given how the theoretical overview detailed in Chapter 2 highlights *partial objectivity* or *situation* as being crucial to how this thesis understands how Cherish practitioners produce

data, the same concerns should be reflexively applied to any consideration of the data I generated through the methods outlined above. Much of this concerns my own positionality as a researcher; my familiarity and experience with specific geospatial technologies, for instance, or the theoretical literature I had consulted in the first year of my project.

Conversations with Cherish team members were complicated by the theoretical vocabularies I shared with my respondents. As I have already noted, early in my correspondence with Anthony Corns, for example, he remarked that my planned fieldwork sounded "Latourian". Understanding Anthony's potential familiarity with some the literatures and concepts I intended to bring into the field necessitated thinking about how I would structure our interviews together. Would I steer the conversation away from such discussions, focusing more on the practical or technical aspects of Cherish work? Would he cater his responses in a way that anticipated my theoretical interests? The converse, of course, was also often true. In my interviews with respondents like Robert Shaw or Toby Driver, for example, I quickly found that posing questions directly derived from my theoretical research would often lead to confusion between us. As such, I was constantly anticipating and watching out for these frictions or overlaps as I conducted my interviews, evaluating in the moment how best to pitch my questions.

In the context of on-site participant observation, I consistently monitored the degree to which my focus or energy was being directed by my familiarity with the procedures being executed. Having completed the aforementioned digital visualisation courses at the University of Brighton early in my DPhil training, and having a professional background working with geospatial technologies, I was ever mindful of the fact that either experience could accentuate aspects of my observational faculties and compromise others. If I focused too directly on what was familiar to me, what might I miss? How could any of these factors influence my efforts of description? Furthermore, the same challenges also carried into my

experiments with Cherish data, where both my engagement with the softwares, platforms, and datatypes used ─ and my description of these engagements ─ would inevitably be influenced by my previous training and background.

Another challenge to the project was finding the means of stitching together the inherent multi-sitedness of both the workflows observed and the relationships between the disparate partners I was observing. Considering that practitioners from either the Discovery Programme or RCAHMW operated in accordance with both project-wide protocol[27] *and* within the habituated protocols unique to their parent institutions, collating data derived from engaging with both Welsh and Irish respondents/sites required thoughtful consideration. Part of this concerned how the teams from either Discovery or the RCAHMW should be understood as *communities*, where their approach to, or interpretation of, the project's overarching initiatives were respondent to customs and habits of their respective workplaces (Damianakis and Woodford, 2012). Furthermore, because this thesis foregrounds the travelling of data produced as the ethnographic object connecting multiple sites of production, acknowledging these institutional characteristics necessitated looking for articulations of the same in the data that members from either team had volunteered.

It is worth considering how my very presence as a DPhil researcher, embedded in what would normally be standard project procedures, influenced or changed the performance of observed activities. Given that my fieldwork resulted in productive overlaps as it moved between sites of production ─ interviews into observation, observation into interviews, etc. ─ I had to remain aware of how earlier conversations would feed back into the enactment and observation of procedures at later stages. If, for example, Robert Shaw drew extra attention to an aspect of his work during UAV survey *because* he had remembered discussing

[27] Which, it should be noted, as a deliverable of the project overall was often changing and evolving as the project unfolded.

it in his entrance interview, how might that added emphasis influence the data produced? This was particularly true of the task-based interviews, where Robert and/or Daniel's engagement with the processes being enacted was directly generative of, and subsequently responsive to, the interviews being conducted. In the analysis of my own data, then, I had to consistently consider the consequences of my own involvement.

3.12 Ethics

Outside of acknowledging my own positionality as a cisgender, white, American male observing a collective process mostly composed of British and Irish nationals with complementary, if not similar, educational and professional backgrounds, the ethical considerations of this project are primarily centred on questions of intellectual property. Given the technical nature of the expertise and practices observed—and particularly in light of the attendant focus my fieldwork turned towards individualised expressions of skill in practice—any type of disclosure of said methods was carefully negotiated with my respondents from the outset. Part of this was made easier by the fact that all Cherish data is already stored and circulated under a creative commons license. So, while much of the project data has yet to be hosted on portals accessible to the public, it already exists as an open-source resource. As such, any sharing of Cherish data between practitioners and me was exchanged under the full expectation that it would be discussed and featured within this thesis as it currently exists on Cherish servers. In a broadest of senses, none of my respondents were considered vulnerable, nor was the work either observed or discussed sensitive. As such, all the fieldwork was executed in accordance with the corresponding CUREC guidelines reviewed and approved by the University of Oxford ahead of travels to

Ireland or Wales. Because Cherish is a large and rather public facing project, the names of my respondents, likewise, have not been anonymised[28].

3.13 Analysis

The analysis of the data generated by all these methods was conducted with the help of two primary data-analysis softwares. The transcripts generated through interviews and on-site observational notes were processed using NVivo. I began by developing a codebook based around four core thematic nodes: "*Assemblage*", "*Digitality*", "*Sites and Situation*", and "*Practice and Performance"*. In a manner partially derived from grounded theory, these themes were seen to "emerge" from the processual comparison of datasets as they accumulated (Strauss, 1998). Nestled within these core nodes were clusters of sub-nodes (see codebook, appendix III, for the full list). Developed around both theoretical and technical themes, this coding framework was then applied to the transcripts of interviews, field notes, and the official literature associated with the Cherish project (technical manuals, funding charters, etc.). Once coded, these inputs were then processed in NVivo. Here I ran "code queries" based on the overlap of specific codes associated with a piece of text. The outputs of this coding were robust and productive, generating high density clusters of overlapping content which have served as the primary basis for three empirical chapters to follow. As for the data I acquired directly from the Cherish archives (raw images, scans, and coordinate info), I used these files to replicate the visualising processes I had observed in Cherish offices. I would often pursue this by following the official protocol documents Cherish practitioners use themselves. Additionally, however, I would experiment with these datasets and softwares, testing what might happen if I processed such data within different thresholds

[28] As documented and agreed upon through the standard CUREC forms of written consent.

than those prescribed by the manual. I further analysed the metadata attached to these datasets via the content analysis methods already mentioned. As such, there is a way in which these methods of analysis served as both a field method *and* as a platform from which to analyse data.

3.14 Conclusion

Before heading to the field, I found myself simultaneously attempting to both clear my head of expectation and refine the theoretical tools and questions I would bring with me. I had a rough idea of how many of the acquisition and processing methods I would observe ostensibly worked. I'd completed several introductory courses on some of the visualisation softwares I expected to encounter. I felt I had done my homework, so to speak. And while I wanted to make myself as receptive as possible to the observation of the unexpected, I had also primed myself to watch for specific things. My interviews were deliberately semi-structured. I required daily tutorials and instruction as a participant observer at field sites. I began as a novice in my experiments with photogrammetry softwares. Within each of the Cherish methods observed I aimed to generate my own empirical data either by learning through demonstration and example or by undertaking pieces of the work myself. In any context, however, my methods were also organised around attending to key themes and conditions already outlined in this thesis; namely, notions of sites, situation, assemblages, and intra-action as well as interfaces, networks, and frictions.

Chapter 4: Sites of Acquisition

4.1 Introduction

How does the production of digital heritage objects begin? What does it mean to *acquire* the data used to produce them? This chapter explores these questions by tracing several of the procedures followed by Cherish Project to produce data in the field. All the respondents interviewed in this study use the term *acquisition* to describe these processes. The choice of words indicates something crucial about the way Cherish practitioners conceptualise their field work and surveys; namely, that the data they require is always already present at field sites, simply waiting to be "acquired". This chapter addresses how the enactment of data acquisition is actually predicated not only on a field site being *assembled*, but that the resulting data is *produced* through these acts of assembling.

Following practitioners from both the RCAHMW and the Discovery Programme, this chapter is structured around my observations of three of their principal methods for "acquiring" data: UAV survey, laser scanning, and analytic walkover earthwork survey. Each method, this chapter shows, requires the site-specific and situated enactment of procedures that Cherish practitioners perform upon, within, or around heritage landscapes, features, and monuments. Individually, each of these approaches requires the unique assembling of technical instruments and performed expertise, all of which collectively can resolve in a variety of data types. Not only does every method require its own instruments and tools, but the execution of such methods also requires practitioners to engage with targeted landscapes and features in situated ways. As a result, the datasets produced through UAV survey, laser scanning, and analytic walkover earthwork survey[29] are not only all different, but reflective of the situated socio-material assemblages specific to each method.

Through both the assembling of acquisition sites and the enactment of protocol specific to chosen methods, practitioners acquire their data by spatialising sites of acquisition

[29] To be abbreviated throughout as "GNSS walkover survey".

in different ways. These acts of spatialisation result in the production of what this chapter describes as "spatial registers". These spatial registers not only determine how practitioners engage with landscapes/features they survey, but further serve as the primary means through which the data produced becomes mobile, further enabling it to be distributed across other sites of production and reassembled as cohesive models. It describes and enumerates these spatial registers in the following four ways:

1.) The “unproblematic” or “self-defined” spaces Cherish practitioners associate with the physical landscapes and features being surveyed (i.e., the natural boundaries practitioners see determining what requires surveying).

2.) The abstract/virtual spaces (articulated through global positioning systems) which practitioners bring *to the field*. Practitioners register sites of survey in reference to satellite networks in the field in order to ascribe geographic coordinate systems and regional map projections to the data produced through a given survey method.

3.) The local spatial networks assembled by practitioners in order to perform site-specific measurements and observations. This commonly requires registering fixed coordinate readings for key markers distributed across a site of acquisition, thus enabling practitioners to geo-reference key features identifiable in photographs or scans at later stages of processing.

4.) The spaces *described* by practitioners through the performance of observation, image capture, and measurement.

This chapter begins by providing an overview of all the acquisition methodologies gathered under the Cherish scheme. In so doing, the chapter not only outlines when, where, and why certain methods are pursued, but how Cherish investigators see individual methods relating to one another within the over-arching context of what the project aims to achieve and deliver. From here the chapter traces the production of spatial registers outlined above across the three methods observed in the field. The first of these sections ─ *Assembling a site of "acquisition"* ─ addresses how practitioners spatialise the sites of survey based on what is already present in the field (i.e., the "unproblematic" or "self-defined" spaces mentioned above). In so doing, it describes not only how practitioners choose methods based on these initial understandings of the sites they target, but how the relationship between a site to be surveyed and the chosen method of survey intra-act relationally to define the resulting data

and visualisations. The next section — *Spaces of reference and measurement* — concerns how practitioners spatialise sites through abstracted and virtual spatial registers, as well as the methods they use to distribute and register locative information across a site of survey. In particular, this section concerns the distribution and registration of what are known as "control targets", a procedure which ensures this locative information can be translated into the resulting visual datasets at later stages. The final section of this chapter — *Spaces of description* — concerns the spatial registers assembled in order to produce both digital imagery and exhaustive coordinate-based observations of sites being surveyed. Here these processes are described as being critically based upon — and responsive to — the spatial registers produced throughout each stage of acquisition. As a result, it reveals how the systematic production and translation of spatial registers — even within the context of a single survey — enable the data produced to move from the field to the office, where they can later be re-assembled as digital objects. It also points to how the habituation of protocols and regulated performance — after DeLanda — *territorialise* the Cherish Project workflow as an assemblage, both ensuring its cohesion across multiple sites of investigation while maintaining standards of accuracy for the resulting data and visualisations produced.

The situated production of these spatial registers at sites of acquisition is seen here to be iteratively translated and inscribed into the resulting data at the different stages of acquisition procedures (primarily via metadata). These inscriptions and translations are further propagated and redefined as such projects iteratively develop into digital heritage objects. Attending explicitly to data acquisition, then, is paramount for two reasons. On the one hand, the principal stages of acquisition point to how both the assembling of an acquisition site *and* the intra-action of the components there assembled begin to co-constitute the knowledges that emerge through these processes. In a bigger picture sense, too, actively tracing the relationship between the *different* acquisition methods assembled under Cherish

(from UAV to GNSS survey) helps to demonstrate the impact such methods are having on the production of archaeological knowledges more generally.

4.2 The Cherish Toolkit

The Cherish Project employs a range of methods to acquire data from their chosen sites of investigation. Depending on factors such as the size of the site being targeted ─ as well as the outputs for which data need be produced ─ aerial photography, LiDAR, geo-physical survey, UAV survey, laser scanning, and GNSS survey all find distinct application within the Cherish scheme. As it concerns the project's specific aim of monitoring the active collapse and erosion of coastal heritage sites, UAV survey, laser scanning, and GNSS walkover survey are those which are repeated at regular intervals and reliably resolve in datasets that are comparatively analysed as visual models at later stages. Not only has the majority of the data produced by the project already been rendered through these methods, it is through them that the project aims to develop "best practice" protocol for future monitoring projects as well. For Cherish practitioners, however, all these methods are viewed as being complementary, collectively composing something of a holistic approach for achieving their research initiatives[30]. In the months before joining my respondents in the field, I travelled to both Dublin and Aberystwyth to conduct a series of entrance interviews with each respondent at their respective home offices. A substantial part of these conversations was centred on discussions of how each of the respondents viewed the project's methods of survey ─ individually and collectively ─ relating the data and visualisations the project had already produced, and how these methods and outputs were assembled to address the goals of the project overall.

[30] See appendix I

At the outset of my field work I travelled first to Dublin in the late autumn of 2018. My first day in Dublin was almost entirely confined to the second-floor office that Anthony Corns (Discovery's technology manager and principal Cherish officer) shares with both Robert Shaw (Discovery's senior geo-surveyor) and Aaron Deevy (the Programme's principal 3D modeller). Anthony organised our first formal conversation around a 200 slide PowerPoint presentation through which he could outline and illustrate the evolution of digital methodologies he had overseen in the 17 years he had managed the department. I was blitzed through the early days of photogrammetry (late 1990s—early 2000s), the arrival of LiDAR (early 2000s), laser scanning (2007), and the advent of Structure From Motion[31] (2010s). Each of the discussed methods was elaborated through the discussion of specific cases and projects, ending with an extended discussion of the Cherish Project. When applicable, Anthony would rummage through the equipment cases to better demonstrate what was used where. Together we unboxed two drones, a laser scanner, a drone-mountable multi-spectral imaging device, and a selection of accessories used to optimise the performance of these respective tools when in the field (*figure 4.1*). Doing so served the very simple task of introducing a range of hardware and implements that—up to this point—I had mostly only read about. Yet what further materialised through this exercise was how the intersection of methods, tools, and visual products served specific research questions or goals. Projects requiring drone survey, for example, were introduced in tandem with both the unboxing of the office's DJI Phantom IV (their stalwart drone), as well as brief overviews of the corresponding softwares used to process the images and data such tools

[31] A method of photogrammetry wherein sequences of two-dimensional images are used to approximate three-dimensional forms. The name, *structure from motion*, alludes to principle by which the human capacity for discerning three-dimensional forms is based in moving around them or observing an object move itself. In practice, Cherish teams use drones to photograph areas of interest from both orthogonal and oblique angles which, when taken collectively, comprise a comprehensive and exhaustive visual overview of the site or feature in question. Software such as Photoscan is commonly used to render these sequenced images as cohesive geometric forms.



Figure 4.1. *(Top left) The Discovery Programme's newest drone, a multi-copter UAV that has thus far proven too large and heavy to effectively be used at the majority of Discovery's Cherish sites. (Top right) A drone-mountable multi-spectral imager, a remote sensing device which separates the bandwidths of reflected light readings into unique values. Multi-spectral imaging is very effective at analysing the content of scanned materials in sites or objects composed numerous metals, clays, etc. (Bottom left) A calibration tablet for multi-spectral imager, a simple but crucial implement used to set a flat baseline for colour based readings taken by the device on site. (Bottom right) A Faro "time-of-flight" laser scanner, A very mobile and dynamic machine which the Discovery Programme uses often in its work for the Cherish Project. Source: photos by author.*

produce. As a result, it gradually became evident that the particularities of targeted sites/landscapes required specific assemblages of instrumental technology and expertise in order to acquire the highest possible quality of data for a given task. Part of the benefit of moving quickly between the Discovery Programme's methodologies and projects was that it also provided an overview of how these different tools and methods collectively compose a dynamic toolkit capable of undertaking research and monitoring on wide-ranging regional and scales[32].A single aerial survey flight, for example, is capable of prospecting numerous sites along miles of coastline in a single afternoon. UAV survey, by comparison, is mobile and quick enough that practitioners can collect data from sites as soon as the day after a severe storm event. Taken together, they provide a spectrum of datasets for monitoring sites at granular scales, which, in turn, enables the project to make assessments about the impact of climate events on heritage locations on regional (if not national) levels.

Anthony explained the matching of methods to landscapes/features as a process of where questions about the total area being surveyed, the desired resolution of the resulting data, and the cost of the execution were all considered (Corns and Shaw, 2009). In many respects the general takeaway was this: the larger the area being surveyed, the more expensive the method, and, as a consequence, the less likely it would be repeated throughout the duration of the project. The Discovery Programme outsources its LiDAR scanning projects to private contractors, for example. Aerial photography requires getting a practitioner in a hired plane with a hired pilot for the better part of an afternoon. Methods like UAV survey, laser scanning, and GNSS walkover survey, however, require comparatively little overhead outside of the original investment in equipment. Through these methods, then, the Cherish Project is able to not only able monitor it is chosen sites repeatedly throughout the

[32] Discovery's research sites cover most of the eastern and southern coastlines of Ireland, the Royal Commission's cover nearly all of the Welsh coastline.

year, but to produce robust datasets that actively reflect the on-the-ground dynamics of their chosen features and landscapes.

In my entrance interviews with Daniel Hunt (principal investigator for Cherish at the RCAHWM) he specifically spoke to how all methods gathered under Cherish complemented and related to one another. This assemblage of methodologies, he claimed, collectively cohered into a holistic methodological toolkit for pursuing the project's over-arching aims. To illustrate, he made a hasty sketch of an inverted pyramid with each of the project's methods sorted into stratified levels. The pyramid structure, he also explained, helped to illustrate how each of the levels corresponded to how close a method of acquisition brought a practitioner to physical landscapes or features they targeted (*figure 4.2*).

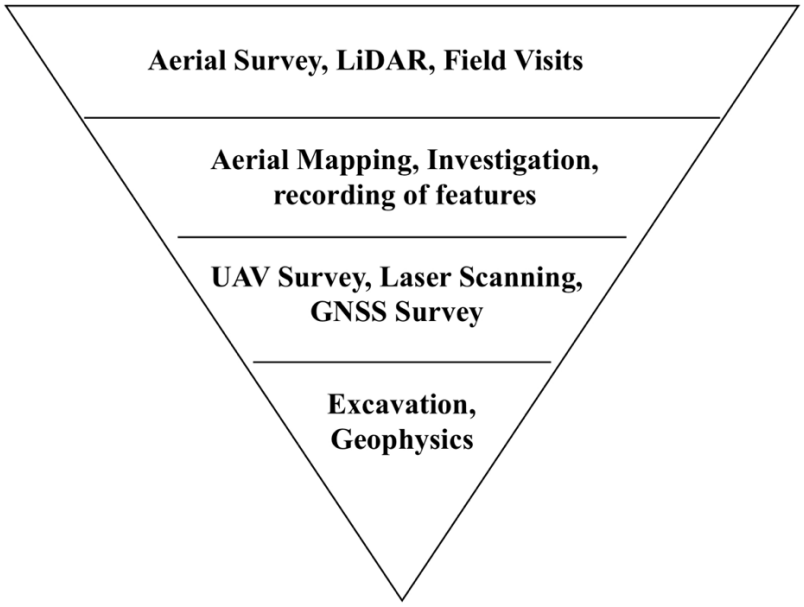


Figure 4.2. *Daniel Hunt's methodological pyramid. The levels of this diagram have been organised as a pyramid to indicate the spatial scale constituted by each of the given survey methods. Aerial Survey and LiDAR, for example are capable of surveying areas in square kilometers. Excavation and geophysics, by contrast, are carried out at discrete headlands and promontories. Source: a replicated drawing done by author, based on the original drawing by Daniel Hunt.*

At the top were what he typified as the "reconnaissance methods"; namely, aerial survey (photography), LiDAR, and field visits. These, he explained, either already had been, or

would be, carried out at each and every one of the field sites the RCAHMW had grouped within the Cherish scheme. Not only were such methods commonly executed from way up in the air, but the acquisition data they produced largely functioned to provide wider-scale context acquisition methods to be enacted at later stages. Next were what he typified as the stages of recording or documentation of specific features generated from the investigations enacted at the first level; i.e., the derivation of cartographic products from the reconnaissance stage[33]. The data acquired at this level provides practitioners with the tools to not only better navigate sites, but to assist in the planning of the data acquisition enacted at level 3. The third level, then, pertained directly to "site-specific" interventions generally grouped around the repeated enactment of UAV survey, laser scanning, or GNSS walkover survey. Finally, the fourth level of the pyramid pertained directly to what he described as "invasive techniques" for acquisition, such as geophysical survey (magnetometry, resistivity, or ground-penetrating radar) or full-scale excavation.

Taken individually, each of the sections of Daniel's pyramid indicates the scope, resolution, and potential applications of the data procured at a given stage or in a certain context. What became evident through our conversation, however, was how the interrelationships of these data can cohere or gel into unique and complex knowledges. The monitoring conducted within the third level—UAV survey, laser scanning, etc.—primarily assists in both documenting and assessing land loss/erosion, for example. On the other hand, the "invasive" acquisition methods gathered within the fourth section of the pyramid would bring Cherish investigators closer to the desired understandings of "the archaeology"[34] at a given site:

[33] This, it should be mentioned, might pertain to either on-site or off-site activities.
[34] Across all the practitioners interviewed I was surprised by how each employed the notion of archaeology as a proper noun, inherently marking specific features or monuments as somehow distinct and crucially different from the landscapes that frame or enclose them.

> So level four is kind of all of the above but including more invasive techniques. So that would be excavation, geophysics. So now you are getting down to the more traditional techniques, but this is purely to get a further understanding of the archaeology there. I guess the bread and butter of the project is happening at level 3, actually. That's where you carry out your monitoring, that's where you begin to quantify loss and stuff. But in terms of further understanding sites, that's level 4…that's kind of a combination of the three prior to that (Dan Hunt, Lead Cherish Officer, RCAHMW, interview 3/25/2019).

As a consequence, then, the "bread and butter" of Cherish—i.e., the repeated monitoring and modelling of heritage landscapes in flux—was discussed here as being foundational for the later enactment of archaeological methods normally discussed as being "traditional". Simply put, data derived to quantify land loss help Cherish practitioners decide when and if excavation is warranted (i.e., if pursuing an invasive method of acquisition is time sensitive to a site's active collapse or erosion). The inter-relationships of the data and knowledges associated with these complementary methods underscore the fact that these knowledges are not distinguished from one another by key differences, but through their arrangement in a larger workflow scheme have already contributed to a shift in how Cherish pursues "traditional" archaeological methods (such as excavation).

One of the more notable aspects of the pyramid model Dan provided was how nearly all of the methodologies it gathered and organised (save for certain aspects of those described in level 2) concerned the "acquisition" of data, rather than its processing or visualisation at later stages. As a result, it became evident that how data was acquired was crucially co-constitutive of both the differences between the datasets each method could produce, as well as the knowledges they could respectively carry. The methods outlined at level 3 in particular (UAV survey, laser scanning, GNSS walkover survey) are notable for several reasons. Not only do such methods repeatedly bring practitioners to their targeted research sites with regularity, but it is through them that the Cherish Project most directly addresses ─ and becomes entangled within ─ the active and dynamic changes of these heritage landscapes. As the starting point from which the majority of Cherish's digital heritage objects are derived,

methods like UAV survey, laser scanning, and GNSS walkover survey therefore serve as the most logical place to begin tracing the translation of heritage landscapes into digital objects.

4.3 Assembling a site of "acquisition"

To a certain extent, the assembling of components that define "sites" of acquisition are shaped by specific factors of predetermination. Regardless of the specific method being pursued, much of the Cherish workflow is defined by the relationship between three factors:

1.) The capabilities and limitations of the instruments and technologies at the project's disposal.

2.) The personal expertise of the practitioners charged with specific tasks or projects

3.) And—in some cases—by certain legal limits or restrictions[35].

Cherish practitioners also maintain that many of the sites and locations they target for acquisition have a propensity to "define themselves" (Robert Shaw, Interview, 25/11/2018). In such cases an assumed area of interest would be "defined" either by a site's geological composition or the presence of clearly defined archaeological evidence/anthropogenic features. Often the negotiation of these factors is reflexive, where the "self-definition" of a given site likewise demands specific technologies in order to be digitised (and, occasionally, vice versa). Furthermore, sites of acquisition are also assembled in accordance with the visual imaginations of the practitioners themselves, a faculty determined by the practitioner's familiarity with both the landscapes being targeted and the technical instruments or methods being used to digitise them. Finally, the assembling of acquisition sites is further determined

[35] Within both Ireland and the United Kingdom, for example, any drone or "unmanned aerial vehicle" is legally bound to fly no further than 120m above a given pilot and within a radius of 300m of the same. The result, then, is something of fixed boundary; no site selected for UAV survey can exceed a corridor of 600m.

by how the chosen method relate to other methods either already performed at the same location (see Daniel's pyramid above) or to be performed at later stages of processing. Assembling a site of "acquisition", then, is a multivalent process wherein conditions of predetermination are counterposed with the situated circumstances of the actual enactment of a chosen method.

Both the scope of an acquisition project (i.e., how much of a heritage site's area it can cover) and the type of data it will eventually produce conform to the capabilities of the technologies and instruments available to Cherish instigators. Laser scanners, for example, are often distinguished from one another by whether scans are performed via "time of flight" or "phase-based" operations[36]. The primary scanners for both Discovery and the Royal Commission are both "time of flight" apparatuses manufactured by FARO. The reason for this is that time of flight scanning is better at managing areas of greater distance and size, which—given the structural or monument-based nature of the sites/targets requiring scanning within the Cherish remit—make them ideal for most Cherish sites[37]. Drones used in acquisition are likewise chosen on the basis of their respective capacities to complement or capture the contours of the site being targeted. Contemporary literature on UAV survey is rife with discussion concerning the fitting-together of appropriate technologies with site-specific conditions to reach specific research aims (Chiabrando et al., 2018; Corns and Shaw, 2009; Drap et al., 2017; Fish et al., 2017; Ortiz-Cordero and Hidalgo, 2017; Thomas, 2018; Murphy et al., 2017). The selection of specific drone types—from fixed-wing to copter models—is predicated on a given apparatus' ability to stay in the air for a certain length of time, or to

[36] Time of flight scanners operate by calculating the time it takes an emitted laser to leave and return to the scanner. With the speed of light taken as a constant, the computer within the scanner is then capable of estimating the position of objects based on their time of flight. Phase-based scanning, on the other hand, is structured around the internal interpretation of interference, or "backscatter", registered by the scanner after laser pulses have been emitted (Lillesand, 2004).
[37] Structured Light-based scanning and phase-based scanning, by contrast, is particularly useful in the digitisation of artefacts and objects, such as those comprising the 3D Icons project the Discovery Programme undertook in 2015 (http://3dicons.ie/).

return images of a certain resolution for a given scope[38]. More important, perhaps, is the fact that the provisional boundaries of a given site can be alternately determined by the "self-definition" of the site itself, the range of the surveying apparatus', or some unique confluence of the two:

> A headland will define itself geographically, as will a sequence of monuments set within a sort of confined landscape. It does get difficult sometimes. Some of the areas we've been working where the waterfront, like there's an area—the Copper Coast—and the Copper Coast is a very, very long stretch of very actively eroding cliffs with a high density of promontory forts. So that's a harder one to call. Sometimes you'd be surveying one and then drifting to the next one. So you do have to consider the capabilities of the drone and the capabilities of the process itself to try and decide what makes the most sense for boundaries (Robert Shaw, interview, 25/11/2018).

It is in negotiating these factors (either of site definition or the capability of their instruments) that practitioners first begin to spatialise their sites of acquisition. Despite the fact that these boundaries are determined through means that practitioners themselves would describe as self-evident or unproblematic, this initial spatial register is produced through the intra-action of the technical instruments brought to the field and a practitioner's preconceived understandings of a site's boundaries.

The assembling of technologies used to acquire data begins with how Cherish practitioners spatialise a site of acquisition ahead of a survey. As processes of acquisition develop, however, the selection of these technologies plays a significant role in determining how they will *continue* to spatialise sites of acquisition as the work progresses. One of the standard Cherish protocols for drone survey—particularly as it pertains to the series of orthogonal photographs captured within the process—is the use of the flight-path programming application "DJI Groundstation". As a proprietary software designed to pair

[38] Fixed wing drones look like model airplanes and are ideal for performing surveys requiring gridded orthogonal coverage of larger areas. Copter models have multiple propellers and are considerably more manoeuvrable than their fixed-wing counterparts, although they are not as good for surveying larger sites. For further information on different types of UAVs, See glossary.

with the DJI Phantom IV Pro drones both Discovery and the Royal Commission consistently use, "Groundstation" not only standardises how the boundaries of a given site of acquisition are framed (and photographed), but impacts how Cherish practitioners have come to approach and execute other aspects data acquisition in the field. While travelling with the Discovery Programme in Co. Kerry, for example, Robert programmed half of the drone flights for our survey of Dunbeg Fort the night before in his hotel room using the Groundstation app on his iPad. As a result, when we began our work on site the next morning, we did so by first consulting Groundstation. Everything, from our distribution of control targets across the site, to the areas and features selected for oblique photography flights, was made in accordance with how this piece of technology had organised our understanding of the site. This relationship between protocols, instruments, and performance became particularly illuminated in a conversation with Daniel Hunt, who—as something of an autodidact in UAV survey or laser scanning—describes his own development and expertise as being crucially shaped by the protocol and technology baked into the Cherish workflow:

> I am a bit self-taught, really, so once I get something—once I use a technology or a software to do whatever needs to be done—I guess that kind of constrains me to what I learn because I'm following a process. And I do try to expand my understanding beyond what I need to do [for Cherish]—which I have done—but because I need to do certain tasks, I am kind of constrained (Daniel Hunt, Interview, 25/03/2019).

The impact of specific technologies or instruments, in these cases, extend beyond their respective "fits" within acquisition objectives. It is not enough to simply contend that certain methods or implements are chosen or pursued because they fit a task at hand, or that they might best capture the scale and contours of a given eroding landscape. Cherish practitioners, in both Ireland and Wales, develop relationships with their tools that crucially feed back into their own capacities to see or interrogate their subjects of study. Much in the way that Janet Vertisi, Natasha Myers, Lucy Suchman, Charles Goodwin, or Keith Woodward have

alternately explored the coherence of "human-computer apparatuses"—or "human-machine reconfigurations"—the assembling of acquisition sites within the Cherish workflow are likewise defined and driven by the productive exteriority between the agencies of the practitioners and the agencies of their tools or instruments (Goodwin, 1994; Myers, 2016; Suchman, 2006; Vertisi, 2015; Woodward et al., 2015).

Something that directly emerges as a result of these agencies working together is the tendency Cherish practitioners have for imagining their visual data and outputs ahead of their being acquired. One of the central and most foundational steps in the processes of deriving either UAV or laser-scanned data is the deployment of what is known as "control targets". In either method control targets serve as geo-referenced markers later used to register acquired data within geographic coordinate systems, thus assuring their accuracy (and by extension, their scientific value). Yet in another sense, the deployment of "control" serves as a means for bounding an area of inquiry, for marking what counts and what's excluded. As such, the conceptualisation and approach to deploying control within a field-site necessitates a visualised ideal of what a given model *should* or will look like, and—in some cases—also serves a prescriptive mandate for how a practitioner should physically move in their performance of their given tasks.

Laser scans, for example, are comprised of individual scans taken from strategic locations encircling a target area of interest. Cherish protocol mandates that at least four of the control targets[39] populated across each of the individual scans must be visible across *all* the scans comprising the project (*figure 4.3*). As a result, the relative success of a scanning project often hinges on a practitioner's capacity to negotiate movement through a targeted

[39] Which are round globes that are recognisable to the visualising softwares that later collate the scan data.

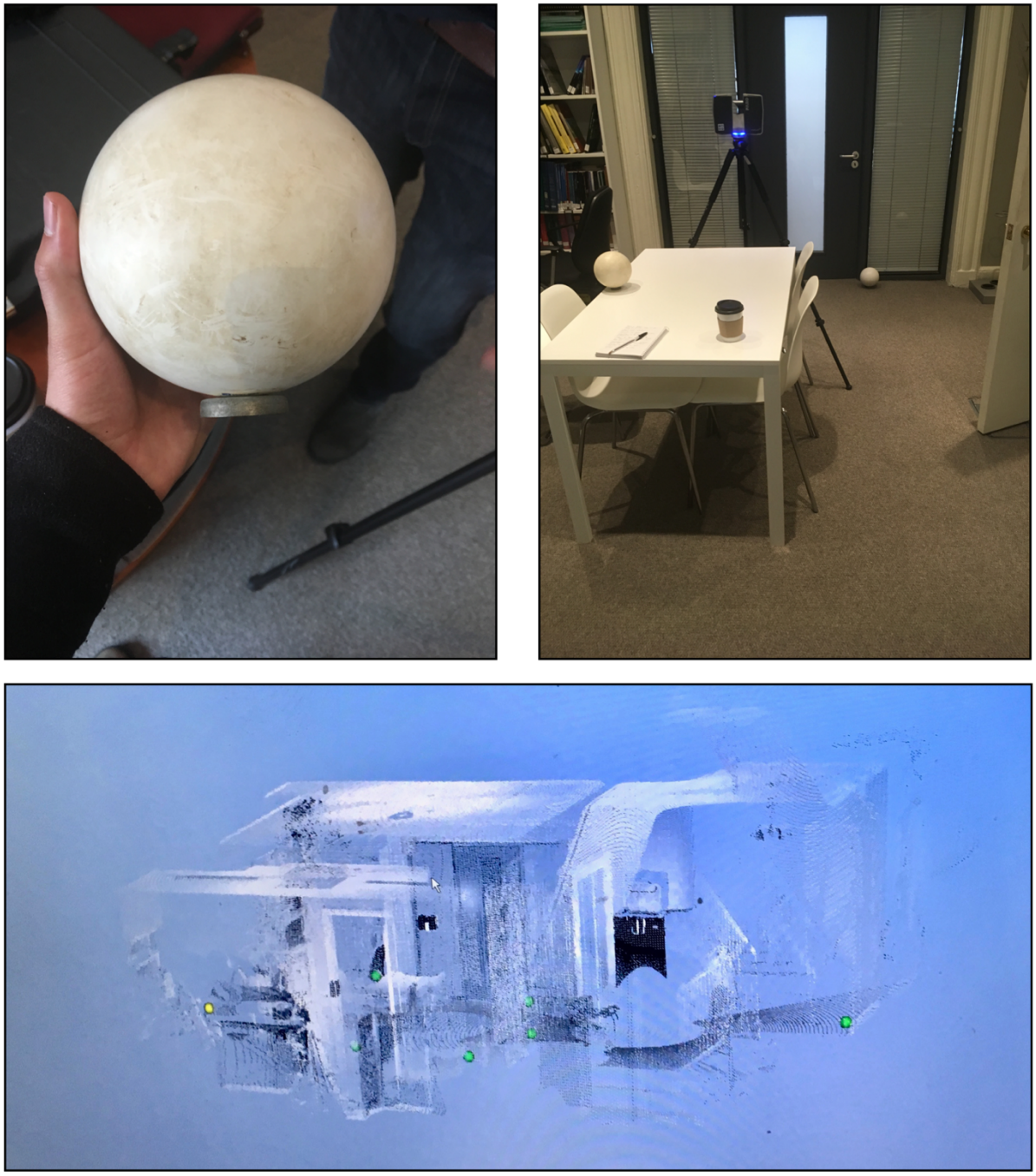


Figure 4.3. *(Top left) Robert Shaw holding one of the registration spheres he uses during laser scanning projects. These spheres are strategically placed around sites of survey at locations with fixed coordinates. (Top right) The distribution of registration spheres during the scanning demonstration Robert conducted on my third visit to Dublin the late spring of 2019. Here we used three individual scans of Discovery Programme's three-room library to produce the model visualised below (bottom image). The green globes in this screen grab indicate where the software has located the registration spheres. In so doing the software is further able to connect and process the three scans together as one cohesive image. The yellow sphere indicates one of the spheres which the software has located but is not certain it can identify as a registration sphere. Sources: top images by author, bottom image a screen grab by Robert Shaw.*

space in accordance with the imagined visual product they aim to produce.

Robert Shaw emphasized this throughout my many visits to Dublin, both in my entrance interviews in November 2018 and during the scanning demonstration he and I would later conduct of the Discovery Programme library:

> It seems very straightforward; you set up a scanner and you press a button and have a chat, you know? And that *is* what happens. But if you haven't planned it properly, if you haven't thought about how this is really just another form of traversing, really—it's like a classic traverse[40] most of the time—and surveyors never want to leave a traverse open. So what you have to think about is how you can close this back, how can you make this as tight as possible (Robert Shaw, Interview, Nov. 2018).

Yet part of what materialises through Roberts discussions of the "tightness", point density, and the precision that result from proper planning, is how acquisition methods are defined as exercises of comprehension rather than interpretation. For Robert, a good or tight scan is about maximising the capacity of the scanner to acquire as many scan points as possible. It is not about "interpreting" the site or feature being scanned in any explicit manner.

It is a question that Louise Barker, Senior field archaeologist and part-time Cherish investigator at the Royal Commission, highlighted when asked what distinguishes UAV survey or laser scanning from the GNSS walkover survey and hachure drawing she does for Cherish:

> One of the reasons I'm still passionate about still being out there and undertaking survey in a traditional way and producing plans, is that it is actually where you are taking the skillset. Is an archaeologist these days going to be responsible for doing the drone and the UAV survey, or a laser scan? Or do you just need a competent technician who understands the kit? They don't have to understand the monument or anything about it, they are there to produce a product which is a cm accurate three-dimensional model of the site. That is what their product is. Whereas it would be very hard to task somebody to undertake a detailed earthwork survey and an interpretive plan of that site unless they had, perhaps, a deeper archaeological background or landscape archaeology background (Louise Barker, Interview, 26/03/2019).

[40] Traverses, in the classical sense of surveying, likewise pertain to the closing or encircling of an area being surveyed.

To distinguish methods on the basis of their propensity to serve interpretive functions, however, runs the risks of framing digital survey approaches as being objective or mimetic. Furthermore, given how theoretical archaeologists such as Ian Hodder or Chris Fowler have argued to dissolve any disciplinary tendency to frame data collection and interpretation as "processual" or fundamentally distanced, methods of acquisition—like scanning and UAV survey—should likewise be considered as having distinct interpretive purchase (Hodder, 1997; Fowler, 2013; Fowler and Harris, 2015). On the one hand, this is readily evident in Robert's contention that "good practice" is critically bound up in a practitioner's ability to engage a field-site in accordance with how they imagine a model being visualised at later stages. Yet this is also evident in the inherent malleability and reflexiveness scholars have located in geospatial technologies (visual or otherwise) for years (Pickles, 1994; Pickles, 2004; Kitchen, Wilson, et al.; 2018). The configuration of specific instruments, methods, and practitioner-based agency assembled in order to "acquire" data at self-defining sites, then, reveals itself to be situationally contingent. Furthermore, the knowledges and visualisations they likewise produce prove to be distinctly emergent as a result of these situational configurations.

Regardless of whether a given practitioner ultimately understands their work to be fundamentally interpretative or objective, their relationships to field sites are both predicated on the theoretical and technical tools they bring with them to the field. Moreover, it is the assembling of these components that ultimately shape what they respectively come to define as a "site" in the first place. As such, the heritage spaces and landscapes targeted for efforts of acquisition are not simply replete with data just waiting to be acquired. On the contrary, sites of acquisition are situationally assembled, with the terms of their assembling directly correlating to what data types there that can then be "acquired". After DeLanda, there is a distinct way in which these conditions can be framed around notions of *territorialisation* or

coding. The “self-definition” of monuments and headlands fit nicely within DeLanda’s primary and spatially bound notion of "territory". Furthermore, the fitting together of prescribed technologies and instruments can also been seen here as maintaining the non-spatial boundaries that might also define sites of acquisition. In another sense, too, it is the habituation of protocol and performance—“the repetition of traditional rituals or systematic performance of regulated activities”—that a DeLandian theory of assemblage (and territorialisation specifically) can most effectively come to account for the regularity or consistency with which Cherish "acquires" its data (DeLanda, 2016, pg. 32). The processual assemblage of field sites, then, is uniquely generative of the registers practitioners develop in order to iteratively spatialise sites of acquisition; namely, those which practitioners come to understand as bounded spaces for investigation. Crucially, however, the configuration of these first spatial registers holds direct and demonstrative consequences, pertaining not only to the questions of *how* and *why* subsequent stages of acquisition are ultimately performed, but to the subsequent spatial registers such performance also engenders.

4.4 Spaces of reference and measurement

What components are assembled at field sites dictates how the enactment of data acquisition is situationally performed. Across the methodologies observed—from UAV survey to GNSS walkover survey—sites are primarily assembled around the establishment, and then distribution, of accurate locative information throughout the area being surveyed. From here, practitioners strategically negotiate the respective “distances” defining the relationships between themselves and with the features, monuments, or landforms they target. In both contexts, questions about performance and movement abound; specifically, how such contours ultimately shape the data being collected. Furthermore, the issues of location and position are variously articulated depending on the methodology being pursued. The

configuration of flight paths for drones and the placement of control targets, for example, both require the use and consultation of a variety of cartographic products (some derived from other Cherish methods or previous surveys, some native to the technologies being used). Regardless of the method being executed, all share their common use of GNSS[41] instruments. Often what distinguishes them, however, is the locative networks they alternately employ to establish in-the-field reference frameworks.

At the sites observed in Co. Kerry (Dunbeg Fort, Dun an Oir, Rossbeigh Beach, Shmerwick Cove), the Discovery Programme configured their on-site locative instruments (Trimble GNSS antennas) through a Virtual Reference Station service (VRS) they access via an annual licensure agreement. VRSs collate readings from satellites adjacent (generally within 20km) to the field-sites being surveyed *at the time* they are surveyed. The coordinate data gathered in the field is then post-processed against the data provided by the VRS, enabling practitioners to refine geo-locative measurements to thresholds of accuracy within centimetres. At the sites observed in Wales (Nab Head, Carfai, Castell Bach, Dinas Dinlle) the Royal Commission established Real Time Kinetic networks (RTKs), which function like VRSs practitioners can erect in-the-field. Using a mobile base station to collate readings from local satellites on-site over an extended period of time, the constructed RTK is capable of making real time locative adjustments to coordinate-based readings made by the roving antennas practitioners carry with them in the field. In either case, the preliminary steps of data acquisition are likewise defined—via different means—through a process of first establishing a spatial network of reference at the site of survey. The significance of this lies in how the prescribed steps that necessarily follow are defined by documenting different

[41] Used interchangeably, GPS and GNSS (or Global Navigation Satellite Service) refer to the means by which individual geo-locative coordinate readings are registered in the field. Commonly returned with readings for northings, eastings, and elevation, Cherish practitioners produce GPS/GNSS data by synching their GPS/GNSS antennas (the RCAHMW uses equipment manufactured by Leica, the Discovery Programme use Trimble equipment) with either *Virtual Reference Stations* or *Real Time Kinematic* networks.

performances of movement and position, and the coding of that performance into the data used to both compose and geo-rectify resulting visualisations at later stages.

Travelling through Co. Kerry with the Discovery Programme team in April 2019, I observed acquisition methods ranging from plane-table drawing to UAV survey. Across all of the activities observed in Kerry, the Discovery Programme's stalwart Trimble GNSS antenna ensured the data being collected was both accurate and commensurate with the archive of previous surveys (*figure 4.4*). Regardless of how this instrument would eventually be put to use in the specific contexts of each survey, measurement could not be conducted until the antenna had been synchronised with an appropriate VRS. This proved particularly problematic at Dunbeg, where—like a cellphone on a subway—the antenna repeatedly struggled and failed to establish the service required to access any local Virtual Reference Systems. Fortunately, through a series of troubleshooting efforts—including phoning the Dublin office for advice—we swapped the SIM card in the Trimble for the one in Robert's phone to make the necessary connection. Without a functional antenna we could still fly the drone. We could still take exhaustive photographs from both oblique and orthogonal angles. We could still enact the entirety of the remaining protocol for UAV survey and the results could ultimately be collated into a striking 3D model of the promontory[42]. Yet without first establishing such networks, without attaching geographic coordinates to either the drone's photographs or our distributed "control targets", the scientific value of the resulting models (particularly in their capacity to be comparatively analysed with other surveys) would be severely compromised, if not nullified.

[42] The DJI Phantom IV drones used by both Discovery and the Royal Commission contain their own GPS sensors (not unlike the GPS in a camera phone), which can be used to roughly approximate and orient a series of photographs in a given photogrammetry software, like Agisoft Photoscan. The issue, however, is that these readings are flawed due to both their inherent lack of precision (simply not up to Cherish standards) and the inherent problem of registering coordinates for a device taking photographs anywhere from 5 to 120 metres above its point of origin.



Figure 4.4. *An image of one of the Discovery Programme's Trimble GNSS antennas at Dunbeg Fort in Co. Kerry. Here pictured while mounted on an adjustable steel rod, these antennas are calibrated by first synching them with the nearest VRS station and then inputting the height to which they've been mounted. The device synchs to a handheld console and keypad through which the practitioner can read the measurements or further calibrate the device. Source: photo by author.*

The majority of the sites gathered within the Welsh[43] remit, by comparison, are remote enough that it is nearly impossible—or at least too consistently problematic—to bother struggling to access a VRS. And it is for this reason that each of the surveys I observed in Wales were structured around the primary establishment of RTK networks on site. Compared to synching an antenna to a VRS, constructing a RTK network is more time consuming and requires considerably more kit. The components the Royal Commission use to establish such networks, conduct walkover earthwork survey, or distribute control targets around sites for UAV survey are all manufactured by Leica and comprise a system of sedentary and roving antennas. Calibrating a base-station (which then enables the roving units and antennae to return measurements accurate to .014 metres) begins with establishing a fixed point of origin (*figure 4.5*). During the UAV survey at Nab Head, for example, the tripod housing the base-station antenna—the motherboard for the RTK network—was carefully sighted over an orange stake which Daniel had driven into a level piece earth. This stake ultimately served as a point of reference for all other coordinates measured at Nab Head. Furthermore, the coordinates specifically registered to this stake not only provided the means through which all remaining distributed measurements would be collated, but—when taken collectively—comprised the abstracted network of performed measurement ultimately used to geo-rectify the photography inherent to modelling the promontory.

Regardless of whether conditions of locative certainty are established via VRS or RTK networks, it is the distribution and registration of control targets across a site of acquisition that ultimately ensures the value of the data being acquired. Much as

[43] While in Wales I observed the undertaking of walkover earthwork survey at Castell Bach (to be later draw up as hachure drawings); I assisted in UAV survey at Nab Head; I observed the drawing up of hachure drawings of Carfai (based on earlier walkover earthwork surveys conducted there earlier that year); I observed excavation at Dinas Dinlle.

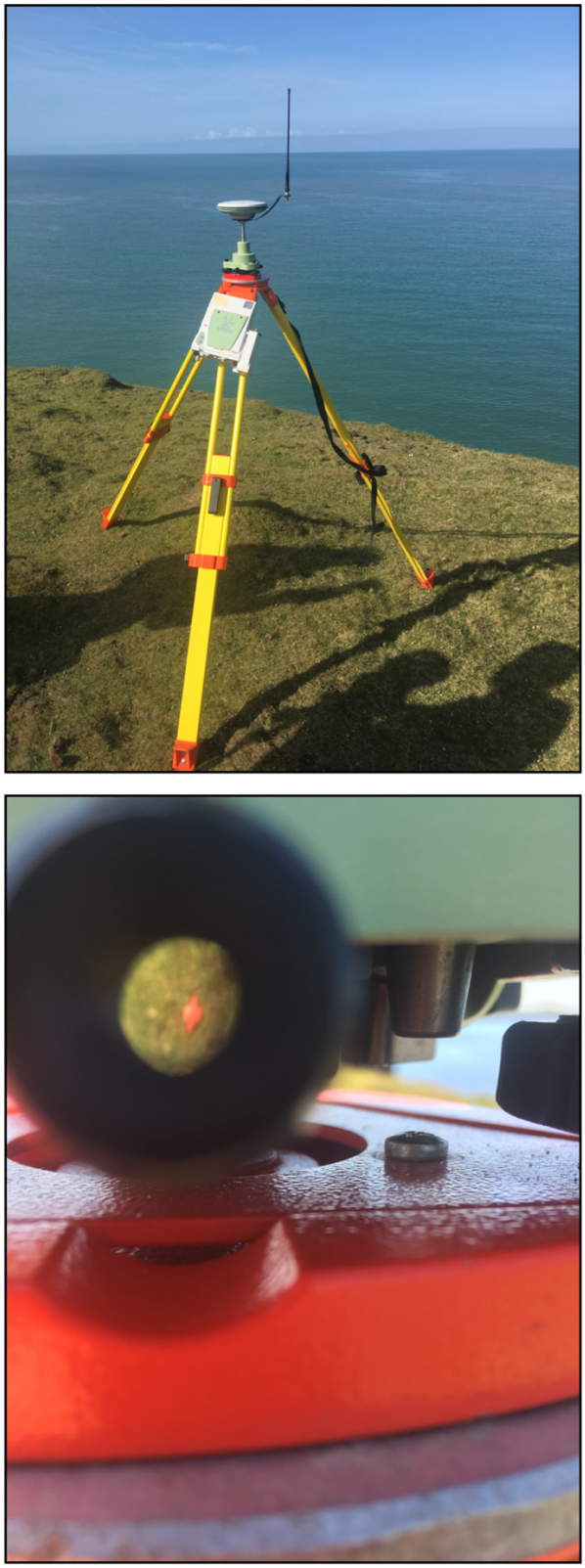


Figure 4.5. *(Top image) the Royal Commission's assembled Leica base station, photographed during a GNSS walkover survey at Castell Bach in Ceredigion, Wales. (Bottom image) the above-mentioned orange reference spike sighted through the view finder on the Leica base station. This sight is used to calibrate the central point of origin for all real-time adjustments made to the roving GNSS antennas. This image was taken at Nab Head where the base station was primarily used to register control targets ahead of drone flight. Source: photos by author.*

methodologies and instruments conform to the site-specific contours of a given landscape or monument, the performance of deploying "control" is determined by the practitioner in direct response to the peculiarities of the site itself. As the primary means through which resulting models and visualisations become situated in the geographical coordinate systems of computational space, control targets serve two primary functions in the field. The majority of the deployed targets compose what will determine boundaries of the resulting models, while a select few of the remaining targets are deployed within these boundaries as a means to check and confirm the accuracy of the locative data to be dispersed across the model. At Dunbeg Fort, Robert and I would distribute a total of ten targets across the site: eight for boundary construction and two as "confidence checks". At Dun an Oir, a total of only eight targets were distributed (six for boundaries, two for confidence checks), despite the site comprising a larger area than Dunbeg. At Nab Head, Daniel opted to deploy all twelve targets at his disposal, despite that particular promontory being the smallest of all I had visited. The differences in approach observed across these three locations reflect both the specific demands imposed by the physical contours of the landscapes being targeted, as well as the habituated tendencies of the individuals conducting the surveys. Daniel, for example, consistently demonstrated a tendency to oversaturate his data[44]. As a result, the Royal Commission's survey data was generally distinguished by both larger image caches and more complex coordinate-based networks. Part of what these differences indicate is the manner in which either practitioner choose to engage and interact with the landscapes and features they respectively target.

Despite their respective differences, however, the process of deploying control targets are relatively similar. Both Daniel and Robert begin by consulting maps to determine where

[44] Whether this holds any significant bearing on the value or accuracy of the resulting models will be addressed in the following chapters.

to begin. Once a path has been determined, both walk the promontories with targets and antenna in tow, registering each target as they go. Across all locations and sites, the enactment of control target registration follows roughly the same protocol. Once a suitable location has been determined the target is staked to the ground (*figure 4.6*). Once secure, the respective GNSS instruments are used to return a coordinate-based reading for the location at the target (comprised of measurements of eastings, northings, and elevation). Each target and its corresponding coordinate set is given a code and stored with the remaining codes generated for the site on an SD card housed within the GNSS antenna. Every target must be readily visible to the drone from the air as well as easily identifiable to the practitioner within the resulting photographs and models produced at later stages. To streamline this process of identifying these targets in processing and visualisation, Robert uses a handheld digital camera to photograph the location of each target as its location is being registered. Rather than photograph his targets as he registers them, Daniel—by contrast—uses a map and clipboard to mark off the location of every target he deploys (which he then likewise consults to identify them in resulting images and models) (*figure 4.7*). In both instances the locative data for each target, their corresponding codes, and the records of their registration are bundled together and commuted from the sites of acquisition to sites of processing and visualisation.

What's significant here is that this bundled cache of data not only functions as both an abstracted spatial network of the site *as well as* a document of performed measurement and movement across such landscapes, but is principally derived from the abstract or virtual spatial registers provided through the RTKs and VRSs. Particularly in the capacity which this bundled data cache is ultimately used to render digital images and their cohesion as point clouds or 3D models accurate, this record of performed measurements points to how the resulting media and visual products are constructed through the gradual assembling of



Figure 4.6. *(Top image) control target T109, one of the ten control targets Robert registered at Dunbeg Fort in Co. Kerry, Ireland. Despite their emblazoned checker design, Discovery practitioners have difficulty identifying the centre of these targets within the images captured by the drone. (Bottom image) Daniel Hunt deploying a control target at Nab Head. The Royal Commission's targets are x shaped and thus much easier to accurately register within the resulting drone images. Source: photos by author.*



Figure 4.7. *(Top image): Robert photographing a control target as it's being registered at Dunbeg Fort. Robert uses these images during processing to ensure that the corresponding codes for each control target are correctly matched with the targets located within the drone produced images. As such, Robert tries to ensure that as much of the surrounding area of the site, including identifying features or landmarks are visible in these images. (Bottom image) Daniel marking the code names for targets on a map of Nab Head. Daniel will use this map during processing to ensure targets are matched correctly with the corresponding coordinates control. Source: photos by author.*

produced spatial registers. Furthermore, the models derived from data acquired at Dunbeg, Dun An Oir, or Nab Head will likely be utilised to conduct analysis and make recommendations on the management of land loss and erosion. As such, they'll possess a distinct potential for making knowledge claims.

In the context of their various applications, however, the resulting models/media are susceptible to the problematic assumption that "scientific images show exactly 'the things themselves as they appear' without paying attention to the considerable work it takes for scientists to produce such pictures" (Vertisi, 2015, pg. 8). The nuanced procedure and performance inherent to acquisition is not readily evidenced in the digital objects they help to comprise. Parsing the relationship between the situated means of production and the knowledges carried by the final products, however, is generative of theoretical discussions about the derivation of scientific information more generally. Ian Hacking and Karen Barad, for instance, recast the performance of measurement or observation in terms of *intervention* and *intra-action,* respectively; reframing the knowledges produced through such means as emerging via the *intra-active* material entanglement of observers *within* the phenomena they observe or measure (Barad, 2007; Hacking, 1983). Within geography, discourses ranging from critical GIS to mobile mapping have similarly foregrounded constructivist and performative understandings of how cartographic knowledges are produced (Pickles, 2994; Wilmott, 2017, Lammes, 2017; Klinkenberg, 2007; Wilmott, 2017; Wilmott, 2020). Contemporary scholarship in theoretical archaeology, by comparison, has responded to the discourse of new materialism by suggesting the material enactment of archaeological investigation (via excavation or otherwise) should be similarly defined by the relationships of entanglement that constitute them (Hamilakis, 2017; Hamilakis and Jones, 2017; Fowler and Harris, 2015; Lucas, 2013).

Yet all of this is complicated by how Cherish practitioners themselves describe their own methods and approaches as being distinguished in terms of either subjectivity/objectivity or interpretive/documentation binaries. A practitioner like Louise Barker, for example, places a distinct premium on the presence she sees as either being afforded or compromised by the methods being pursued:

> Some of the newer technologies, the LiDARs and so on, are brilliant because they allow you to capture something that you cannot otherwise; what the seeing eye cannot see on the ground. That's wonderful. It is really, really good. But I still love going out and undertaking—I suppose it is almost traditional now—the sort of GPS survey or earthwork survey. Because I still cannot think of a different way that you can actually really engage with a site and really feel like you are fully understanding [it]. You're literally in person, walking over that whole site. You're looking at it there, you're looking at that stone thinking, "is that actually part of the original walling?", which you might not actually pick up from undertaking a remote survey where you are stood on *one* spot (Louise Barker, Interview A, 26/03/2019).

It is true that any practitioner engaging in UAV or laser scanning survey might spend the majority of their time engaging with a site in a manner that is inherently *more* mediated or distanced. But all observed methods are predicated on — and subsequently generative of — abstracted reference frameworks that indicate and direct how a given survey can develop. Regardless of whether a given practitioner views their approaches as requiring interpretive engagement with the site of survey or not, all are critically tied to the production of spatial registers that enable them to collate and sequence their observations and measurements. In Barad and Hacking's terms, then, the production of spatial registers via the assembling of reference networks like RTKs or VRSs are defined by the *intra-action* either process requires. Crucial, however, is relationship these performances of intra-action — and the spatialities they likewise produce — have to the iterative intra-actions performed at later stages in the acquisition process. To illustrate, this chapter will continue to trace how the acquisition of data unfolds, moving from the production and assembling of spaces of

reference and measurement to the procedures through which the images and coordinates that are ultimately used to visualise these surveys are acquired.

4.5 Spaces of Description

Once either VRS or RTK networks have been derived, and (in the case of photogrammetry) once control targets have been distributed across a site, practitioners can begin to produce the datasets primarily used to visualise their surveys as models. Across the methods observed, these datasets are the largest of several acquired during any survey (unlike, say, the comparatively smaller datasets which are used to geo-rectify *these* datasets during processing). In UAV survey, this data would be the digital images produced through both orthogonal and oblique photography. In laser scanning, this would be a collection of individual scans, each replete with thousands of individual scan points. In GNSS walkover survey, this would be the hundreds (if not thousands) of individual coordinates acquired while walking across a site using roving antennae. These procedures each spatialise sites of acquisition through means of description and observation; they capture how things "look" and/or are "shaped" within the boundaries already derived for the site throughout the process to this point. To produce datasets that are either explicitly visual (UAV survey, laser scanning) or capable of being visualised through later stages of processing (GNSS walkover survey), practitioners adopt perspectives and relationships to their sites of survey that are mediated not only by the tools they use to produce this data, but how they have assembled their sites of acquisition. What this section addresses, then, is how the production of these datasets is predicated on the "partial objectivity" inherent in these practices, and how this partial objectivity comes to be inscribed in the resulting outputs.

In defining “partial objectivity”, Donna Haraway discusses the ways that the technological mediation of vision has resulted in a problematic tendency to ascribe a false

characteristic of transparency to scientific media (Haraway, 1988). In instead insisting on the embodied nature of *all* vision, Haraway aims to "reclaim the sensory system that has been used to signify a leap out of the marked body and into a conquering gaze from nowhere" (Haraway, 1988, pg. 581). *Partial objectivity*, then, is posited as a theoretical shift through which conditions of distance, position, perspective, and *situation* become intrinsically bound to the derivation of empirical knowledge claims, visual or otherwise. Doreen Massey has addressed similar questions of objectivity, immersion, and distance in her own writings on the configuration of such factors in both field and laboratory settings:

> On the one hand, distance, or height, or standing on top of skyscrapers, cannot lend 'objectivity'; it is still a view from somewhere. However high you climb, however much distance you put between yourself and your object of study, you will still be located somewhere. You cannot pull off the God trick. Objectivity in that sense is not possible. On the other hand, there is no such thing as total immersion; there will always, still, be a perspective, some things will be missed. You will still be producing a particular knowledge (Massey in Pyrke et al., 2003, pp. 53-54).

Photogrammetry proves a particularly interesting test-case through which to consider conditions of partial objectivity and situation. Long before the advent of structure from motion (i.e., the most contemporary iteration of photogrammetry now widely used to generate 3D models), the Discovery Programme applied photogrammetric methods to aerially-derived[45] photographs in order to generate two-dimensional geo-rectified "ortho-images". Every photograph possesses a degree of radial distortion emanating from the focalisers within it. In the case of aerial photography, this distortion becomes particularly exacerbated at or around points of elevation. As such, overlapping images are pixel-matched in order to evenly distribute focus across a collection of photographs, eventually cohering into 2D images that could then be accurately geo-rectified to the pixel. As a result, the

[45] Meaning either the older, larger, models of fixed wing drones popular in the beginning of the century, or with cameras attached to pilot aircraft.

empirical value of a geo-rectified photogrammetric image is rendered through the systematic amalgamation of partial perspectives. Ironically, however, it is this very same process that effectively obscures the partiality inherent to the resulting product once reified as an ortho-image.

Cherish practitioners, like Louise, have a tendency to distinguish digital survey from other more "traditional" methods of acquisition on the basis of their relative capacities to produce "objective" or "interpretive" knowledges. Yet in attending to both the assembling of sites and the acquisition of geo-spatial coordinates necessary to ensure locative accuracy, data acquisition (across all methods observed) is predicated on conditions of contingent or locative partiality. This becomes particularly clear in attending to the enactment of photography necessary to render photogrammetric models of Cherish sites, where the relationship between coordinate and image-based data is determined by ensuring locative measurements are adequately distributed within the scope of the images being collected. As a result, the observed activities detailed below are evidence of how practitioners spatialise sites of acquisition through photography (as in UAV survey) or exhaustive GNSS measurements (GNSS walkover survey). Emerging from series of distinct and assembled intra-actions, these subsequent spatial registers are defined not only by their more immediate correspondence to the archaeological evidence on site, but by how they orient practitioners in relation to such evidence.

The Cherish protocol for drone-based photogrammetry requires two distinct sets of photographs: those which target features orthogonally, and those taken from oblique angles. The value of photogrammetric models is bound up in their capacity to produce comprehensive renditions of Cherish's research sites, which are produced through the cohesion and fitting together of these different perspectives. Orthogonal photography is

principally captured via the use of the aforementioned flight-path application *DJI Groundstation*.

Here, ahead of the flight, practitioners like Robert and Daniel use the application's mapping function to first indicate the total area to be photographed before configuring specific key metrics for the mission. These metrics are crucially inter-related; whether the drone is calibrated to canvas the area in diagonal or horizontal patterns, for example, can dramatically alter the time it will take to complete a given mission[46]. Values for in-flight altitude, likewise, directly effects the desired resolution of the survey. The calibrated number of photos—and whether the camera initiates such photos through "distance-based", "time-based", or "hover and capture-based" intervals—has further bearing on the quality of the images acquired. At the survey observed at Nab Head, for example, Daniel calibrated the following input for their mission for a targeted resolution of 1cm/pixel:

—photo interval: distance based
—flight altitude: 35m
—total flight distance: 4130m
—number of photos: 1012
—time of flight: 46 minutes

Much of this input was configured to conform to the Cherish protocol for image-overlap in orthogonal photography. Each photo, taken in succession, shares a 90% overlap with both the images produced before and after it in the same vertical line of flight. The desired overlap between photos captured in parallel passes, likewise, should share a 60% overlap with its nearest neighbours oriented along its horizontal axes (*figure 4.8*). The dataset/image cache produced, then, comprises an exhaustive overview of the targeted site whereby focus is

[46] Which likewise has an inverse effect on the battery life.

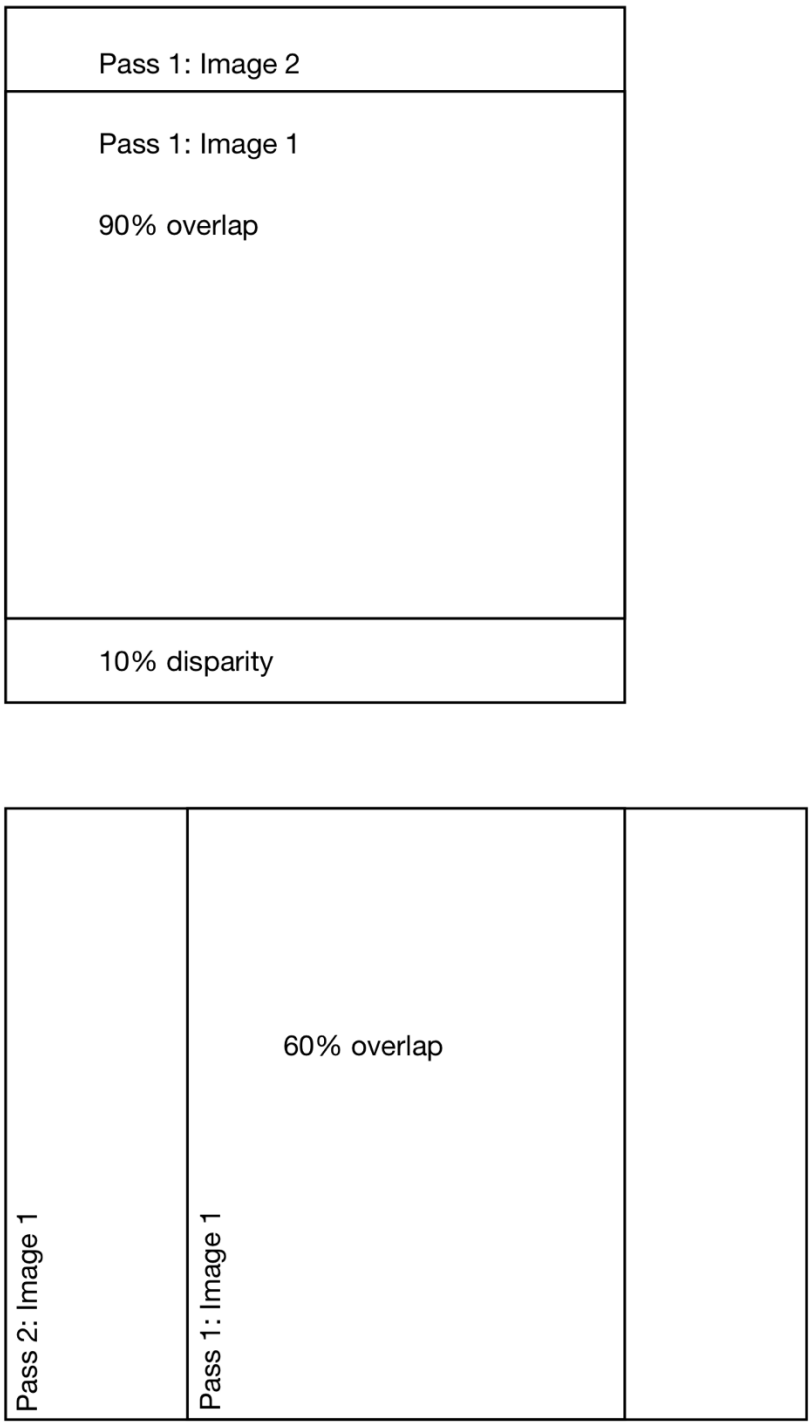


Figure 4.8. *(Top image) A diagram based on a similar drawing Daniel produced for me at the RCAHMW offices in Aberystwyth. The bottom square (Pass 1, Image 1) represents the first of many images hypothetically taken by a drone during the orthogonal flights automated by the DJI groundstation. The second square (Pass 1, Image 2) represents the second image in the same flight. The goal for any survey is to have 90% overlap between any two images taken in sequence. (Bottom image) a similar diagram detailing the relationship between any two images taken during a drone flight which, while not in sequence, have been taken at parallel positions. As above, the first square (Pass 1, Image 1) represents the first image captured by a drone in flight. The second square (Pass 2, Image 1) represents the first image taken once the drone has returned to the bottom of field of survey to begin its second series of orthogonal images. The goal of any survey is to have 60% overlap between parallel images in a single flight. Source: replicated diagrams drawn by author.*

optimised and distortion removed through the eventual integration of all photos taken as one visual product.

There is a distinct way in which both the "piloting" and "photography" necessary to acquire such datasets is almost entirely automated; once the mission has been initiated, the drone lifts off its launch pad, propelling itself upward and beginning to follow its pre-determined course with astounding precision. While the process is underway, Cherish practitioners primarily alternate between watching the drone and their viewing screens, ensuring that the drone both stays it course and captures images at the correct intervals, standing by in the event that emergency piloting becomes necessary. The practitioners are neither flying the drone, nor are they taking the photos. As such, there is an understandable temptation to frame this process in terms of either disembodiment or some machine-facilitated *objectivity*. Yet, much as Anna Munster locates the corporeality or affect of "new" media in the "dispersion of bodily location" across interfaces and networks—or as Deborah Levitt has framed the encounter of human perceptual systems with media environments as being productive of distinct "life-worlds"—the conditions of embodiment produced through this process are re-articulated and mediated through factors of both automation and distance (Munster, 2006; Levitt, 2018). In configuring both the drone and application to certain parameters, a Cherish practitioner's faculties of vision are projected into the sky, where they can see as the drone sees. The inherent partiality of the resulting data, then, is determined by the performed calibration of the instruments, whereby the drone is reconfigured as something of a human-machine lens.

These conditions of automation and distance, however, are articulated rather differently in oblique photography. Given how the bulk of Cherish sites primarily target eroding promontories and headlands, many of the features Cherish pursues through UAV survey are steep and precarious cliff-faces. As a result, the majority of the surface areas that

require monitoring are simply not visible from orthogonal vantages. At Dunbeg Fort, for instance, Robert would conduct a series of four oblique passes with the drone, weaving in and around the headland's western facing cliffs. Contrasted with the orthogonal flight he had conducted immediately beforehand, these series of oblique images were piloted manually. Furthermore, the photographs here acquired were likewise both framed and shot by Robert himself (via the drone's control console). As a result, Robert's relationship to the comprised apparatus of drone, screen, and controller was wholly different than it had been in the orthogonal steps. No longer reliant on the automated regulation afforded by *Groundstation*, metrics of altitude, angles, focal distance, distance travelled, or images-per-flight varied from pass to pass.

Robert would begin each pass from the same point of origin, flying the drone up to an altitude of roughly 30m then piloting it over the cliff face and into the canyon formed by Dunbeg's protruding headland. Here he would move the drone both inwards to the eroding face and outwards and up (sometimes to altitudes of 50m), grabbing both close-ups oriented at straight ahead vantages and partial overviews oriented at angles of roughly 50º or 60º (*figure 4.9*). The resulting variance in aspect or altitude, he would explain, would not compromise the value on the data being collected. Unlike the orthogonal images, conditions of overlap need not be as stringently regulated here. The primary objective here was detail; to canvas the eroding cliff face from enough vantages that the resulting images would share *enough* overlap to be both commensurate between each other and within the larger cache of images of ortho-photos. As such, the "close-up" photographs were framed in order to maximise "object-oriented" pixels in the image, with the remaining images gradually telescoping out and away from the promontory, rendering the overall oblique sets commensurate with the datasets derived through orthogonal photography (*figure 4.10*).

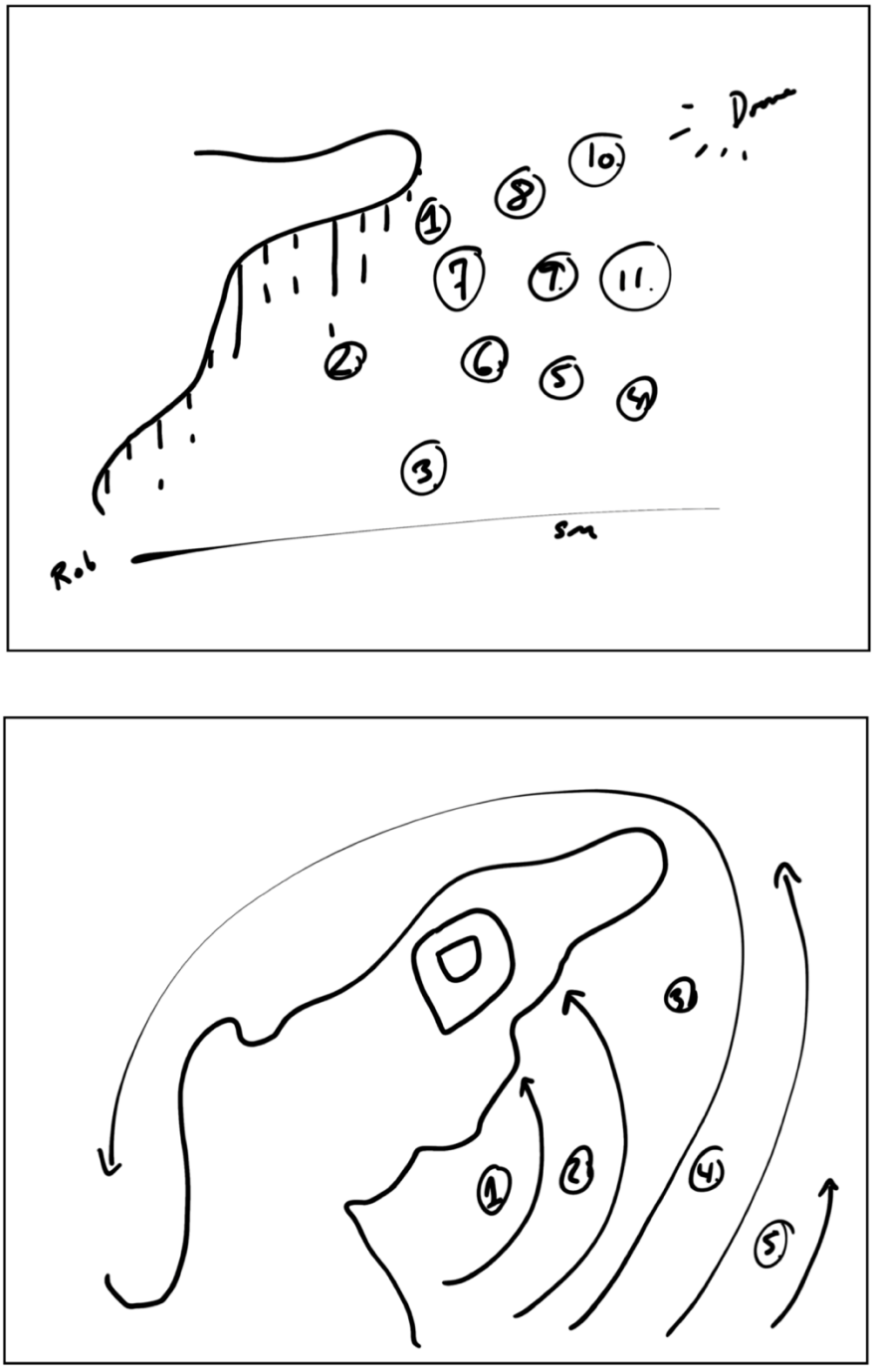


Figure 4.9. *(Top image), a diagram detailing the orientation of Robert (symbolised as "Rob"), myself (symbolised as" SM"), and the various locations of the drone during a single pass of oblique photography at Dunbeg Fort. Each of the numbers indicate the various locations of the drone and the sequence in which it moved from towards and away from the cliff face movement of the drone in-flight at different locations. (Bottom image) Sketch from an orthogonal perspective, The numbers here indicate the sequence and path of the 5 oblique passes Rob piloted at Dunbeg Fort; beginning with short and focused coverage of the eroding cliff face and telescoping out to cover the rest of the headland. Source: drawings by author.*



Figure 4.10. *One of the many oblique images of Robert captured of Dunbeg's rapidly eroding western cliff face. Given that these oblique images will eventually be processed with the exhaustive overheads captured through the groundstation application flights, Robert photographed these cliff faces from as many angles as possible, the goal of which is to eliminate blind spots from the resulting models. Source: photo by Robert Shaw and the DJI Phantom IV drone.*

In contrast to the orthogonal passes, then, the enactment of oblique image capture produced a distinctly different dispersal of vision across the assembled apparatus of acquisition. In simultaneously piloting the drone and shooting the photography, Robert's eyes remained locked on both the screen and controls throughout each pass. Remarkably, in fact, he barely looked at the drone as it was in flight at all. Between the screen of the tablet and the camera mounted to the drone, an interchange between lenses and interfaces enabled Robert to see *through* the apparatus. This was further compounded by the degree to which the performed shifting between vantages might be understood as a process seeking out the necessary perspectives. As such, the conditions of distance or partial perspective bound up in this articulation of both corporeal sight and movement here acquired something of an inverse relationship to the articulation of the same conditions in orthogonal photography. In the case of the latter, the automated regulation of distance, movement, and vision were necessary in order to acquire a specific dataset. In the former, however, the apparatus-assisted mediation of both vision and movement worked to effectively close the distance physically separating Robert from his subject of inquiry. Crucially, however, because it is the cohesion of these datasets that ultimately emerges as exhaustive and accurate 3D models, the respective value of the resulting models is also predicated upon the systematic assembling of partial or mediated perspectives.

In my observations of both oblique and orthogonal photography, across all sites, Cherish practitioners spent little time directly looking at the features they were photographing. Nor did they spend much time watching the drones the piloted. As such, it is not difficult to understand why a practitioner like Louise distinguishes between methods and approaches as she does. This becomes particularly evident when one contrasts UAV survey with the method she primarily practices under Cherish; namely, GNSS walkover survey. GNSS walkover survey is a process where archaeological visualisations (first as point-based

cartographic products, then as hachure drawings) are rendered through the aggregation of coordinate-based measurements produced through the deliberate movement of practitioners across sites and earthwork features. Unlike UAV survey ─ where practitioners rely on drones to project their observational faculties to air-borne perspectives ─ GNSS walkover survey functions to close the distance between practitioner and feature as much as possible, often requiring practitioners like Louise to stand directly atop the evidence they're measuring and recording. While observing one such survey at Castell Bach in Wales, both Daniel and Louise would repeatedly emphasise the sheer proximity the method necessitated between their bodies and the features they aimed to digitise. Here, the GNSS antennas were purposed to effectively trace what either of them might discern as the "phasing"[47] of features present at the site. Furthermore, the coordinates recorded here are correspondingly coded to reflect the individual aspects of feature are being documented (a series of coordinates measured in succession would be coded as the "top of slope", "bottom of slope", etc.) (figure *4.11*). Tracing the banks, ditches, or the empty spaces of entry ways, then, data acquisition in walkover survey is both organised on the basis of what individual features of an earthwork strike a practitioner as being significant (i.e., in relation to their professional training and vision), and is predicated on the movement and positioning of a practitioner above and around these features (Grasseni, 2007). As such, there is a crucial way in which practitioners like Louise distinguish walkover survey from UAV survey, precisely because she views it as a process where acquisition and descriptive interpretation are densely enmeshed in the same process. For Louise, the conditions that render walkover survey *more* interpretive than other methods are the proximity and presence it requires from the individual acquiring the data. Yet ─ as this section has established ─ proximity and presence factor into all methods of

[47] The means through which field archaeologists interpret the composition of earthworks and features as being related to specific periods in history



Figure 4.11. *Louise Barker using a GNSS antenna to trace the top of a slope on an earthwork at Castell Bach, Wales. Louise walks along the berms and banks of these anthropogenic earthworks using both her faculties of vision and the feeling in her feet to determine where to register individual measurements. Eventually cohering as a dataset composed of several hundred measurements, these individual points come to comprise something like a point cloud tracing her movement about the feature. Source: photo by author.*

acquisition pursued within the Cherish remit, albeit at varying scales and through different assemblages.

The processes detailed in this section are the final steps to methods of acquisition. Once drone-photography has been concluded, for example, practitioners retrace their steps to collect their control targets, equipment is re-boxed, and the site of acquisition is effectively disassembled. What this section has specifically traced is how the assemblage of a site for a particular method produces the conditions of partial objectivity that define the acquisition of primarily visual datasets. Furthermore, this section has also addressed the relationship it locates between the partial objectivities determined by the enactment of either UAV or GNSS walkover survey and *how* sites of acquisition are further spatialised through their enactment. As a result, the spatial registers it associates with either the performance of drone-based photography and/or the "interpretive" roving of earthworks in GNSS walkover survey, have here been established as "spaces of description"; spaces which are defined through processes of looking, photographing, and measuring a site. In comparing UAV and GNSS specifically, this section has also demonstrated how partial objectivity is determined differently via a given method, and that this difference is defined via terms of distance, proximity, and presence. Despite the fact that different Cherish practitioners might understand the configuration of these factors as resolving in datasets that are comparatively "objective" or "interpretive" by nature, this section has established that both the final stages of UAV and GNSS walkover survey are defined by situatedness of the assemblages which foreground their enactment. All of these factors ─ ranging from the establishment of RTK networks, to the distribution of control targets, to the way photographs are collected via automated drone flights ─ are inscribed in the resulting datasets. As these datasets travel to new sites of production and are processed into digital heritage objects, the inscription of these conditions factor into how these models ultimately come to cohere. As a result, factors such as the

situatedness defining the assembling of sites of acquisition, the spatial registers produced throughout, and the partial objectivity inherent to the visual data acquired are both inscribed into this data (via metadata) and translated into the resulting digital objects.

4.6 Conclusion

Whether I was travelling with the RCAHMW or the Discovery Programme, the data I observed being produced (through either UAV survey, laser scanning, or GNSS walkover survey) was never a simple or direct documentation of something already evident in the field. The target of these "acquisition" efforts (the earthworks, the built structures, etc.) are never digitised through some self-evident process of mimesis. Rather, they are intricately *produced* – firstly through the site and method-specific assembling of instruments and expertise**,** and secondly through the procedural enactment of the chosen method of survey. Depending on how sites of acquisition are assembled ― and how each respective method is performed ― the derivation of data outputs is shaped by how these stages of assembly and performance spatialise sites of acquisition. In tracing the derivation of Cherish data from planning to the "acquisition" of digital images and various coordinate-based datasets, this chapter has detailed how the production of these spatial registers relate to and reference one another as these processes develop. After Bruno Latour, it is in the relationships between these spatial registers that the systems of circulating reference inherent in the derivation of digital heritage objects at later stages is initially arranged (Latour, 1999).

As this chapter has shown, this begins with Cherish practitioners spatialising sites of acquisition before even going into the field. Not only do Cherish practitioners like Robert Shaw claim that sites have the capacity to "define" themselves (i.e., as protruding headlands or areas with clearly clustered earthworks and archaeological evidence), but often the limitations and/or capacities of survey instruments further determine the boundaries of what

can be surveyed. More precisely, the initial boundaries of acquisition sites are commonly determined by the intra-action of both these factors. Once in the field, practitioners develop new spatial registers through the registration of abstract reference networks via satellites and the distribution of control targets throughout the field. Both processes require the nuanced assembling of more equipment and expertise. It is through these site-specific assemblages that these spatial registers of measurement and reference emerge. Working within the boundaries determined ahead of survey, it is through each of these steps that practitioners ensure the accuracy of geo-locative measurements and, by extension, the distribution of such measurements across the explicitly visual data later produced. Finally, practitioners further spatialise sites of acquisition by conducting photography, laser scanning, and GNSS walkover survey. In digitising sites through either photography, scanning, or more exhaustively distributed measurements, practitioners ultimately produce what this chapter has established as spaces of description.

This chapter has further established that each of these spatial registers is defined by both the configuration of the assemblages that produced them, and the *situatedness* of their assembling. In attending to notions of *intra-action* (i.e., the relationships between assembled components that result in the emergence of "acquired" data and unique spatialities) and *partial objectivity* (the mediating factors of distance, proximity, and perspective inherent to the acquisition of data), this chapter has detailed how the emergence of acquired datasets are determined through both site-specific circumstances and the situated performance of protocol under these circumstantial conditions and arrangements.

The data produced through these efforts are inscribed with unique records of their provenance, commonly articulated as metadata records (Kitchen, 2014). These inscriptions not only describe the contingencies and intra-actions of the assemblages and spatial registers from which they were derived, but they also function as the means through which these

datasets are eventually reassembled as cohesive digital objects. The significance of this, then, is that it underscores just how contingent on factors of situation the production of digital heritage objects is from the outset. As this acquired data iteratively develops into models and visualisations ultimately used to establish knowledge claims in contexts of analysis or outreach, this contingency is carried over and propagated.

In the next chapter we move away from sites of acquisition, travelling with the data to what will be described as "sites of processing and visualisation". There, I will explicitly attend not only to how the acquired datasets are re-assembled as cohesive models and visual products, but how inscribed spatialities and situated knowledges inherent to their acquisition are translated into new digital contexts as they cohere.

Chapter 5: Sites of Processing and Visualisation

5.1 Introduction

The previous chapter established two primary observations about the initial stages of the Cherish Project workflow for the modelling and monitoring of heritage sites. In the first instance, it unpacked and problematised the term "acquisition" as it is used by Cherish practitioners. In so doing, it demonstrated that the observed processes of "acquisition" are not self-evident practices centred on the extraction of already present evidence at field sites. On the contrary, the acquisition of principal data has been described as being *produced* through a nuanced process of assembling the technologies, instruments, and expertise required to make such data accessible. The second observation pertains to how the enactment or performance of acquisition ― itself an iterative process of the fitting together of protocol and procedure ― is generative of distinct and complementary spatial registers which are inscribed into the resulting data derived throughout all of the practices observed.

This chapter, by comparison, concerns the *translation* of this data, and the spatial registers inscribed therein, as it travels from headlands and promontories to offices and labs, and from field instruments to the hardware and software used to generate archaeological visualisations and models. The word "translation" is carefully chosen. Derived from the readings of Latour, Fowler, and Rheinberger detailed in chapter 2, *translation* here refers to the processual abstraction of survey data into cohesive and/or semi-cohesive digital objects via processes of visualisation. Moving from the field to the office, Cherish data travels between and across instruments, operating systems, software packages and interfaces; from GNSS antennas and drone mounted cameras, to SD cards, to hard drives and servers, and ultimately to the softwares where they are visually rendered as models. The consequence of this movement is that ― within a single project ― the data is duplicated, disassembled, edited, or reconstituted, and often all of them simultaneously. As such, the spatial registers

produced and inscribed in the field are reconfigured as a result of many translations, often synthesising or producing new spatialities as the data coheres as digital objects.

As the data moves it changes. Moving from the field to the Discovery Programme or Royal Commission offices in Dublin and Aberystwyth, Cherish data are subjected to a series of subsequent processes that critically reconfigure and situate them in new digital contexts. As such, part of what this chapter will further describe is both how practices of office-based visualisation and rendering facilitate the translation of the data produced at sites of acquisition. It will not only detail how these processes are crucially related to the situated knowledges inscribed in acquired data, but how these processes are generative of new site-specific, situated assemblages and spatial registers. The relationship between *situated-ness* and the production of knowledge, then, likewise carries over here. However, in attending to the specific and gradual coherence of acquired datasets into digital objects, this chapter also aims to parse how the spatial registers generated through field practice remain co-constitutive of the models/objects derived. As such, the iterative development of these datasets into digital objects is again presented as a continuation of the circulating reference described at sites of acquisition. In many respects the cohesion of these datasets as digital objects is predicated on certain factors remaining constant throughout these steps and processes. A developing model's registration with a global coordinate system (GCS) and map projection, for example, is crucial to ensuring the geolocative accuracy of the resulting object[48]. Other aspects of these data, however, change as a result of their processing. Many of the processes detailed within this chapter can be understood as operations of refinement, where extraneous and/or

[48] Map projections ensure that GPS/GNSS coordinates can be visualised as cartographic products with minimal distortion. As two-dimensional renderings of three-dimensional spaces and surfaces, all maps contain some degree of distortion and warping based on these translations. Map projections work by specifically focusing on regional accuracy. As such, a map projection designed for Welsh coastline will be insufficient for charting coordinates taken in Ireland, and vice versa. All map projections are derived from Global Coordinate Systems, which are comprised of fixed coordinates distributed across the globe. The most recent GCS is the WGS84, or World Geodetic System 1984, a global datum produced in the 80s but updated as recently as 2014.

redundant datasets are systematically removed at key stages. Often these omissions are made in order to ensure the processing of what are ultimately large and time-consuming operations.

This chapter traces the secondary processing of data acquired through both UAV survey and laser scanning. It is organised around the step-based protocol practitioners like Robert Shaw and Daniel Hunt respectively follow to produce visualisations like digital elevation models (DEMs) or 3D models. In attending to each of these prescribed steps, it details what of an acquired dataset carries over from one stage to the next, how these processes require new assemblages of technology and expertise, and what emerges in this situation as a result of their collective and iterative co-functioning. This chapter thus develops the central arguments of the thesis by demonstrating how, at these new sites of processing and visualisation, the derivation of digital heritage objects is facilitated through systems of circulating reference distributed across multiple sites of production, the situated assembling of components and expertise, and the processual inscription (and omission) of these situated knowledges as these datasets develop and cohere as digital objects.

5.2 The Cherish Project UAV Processing Workflow

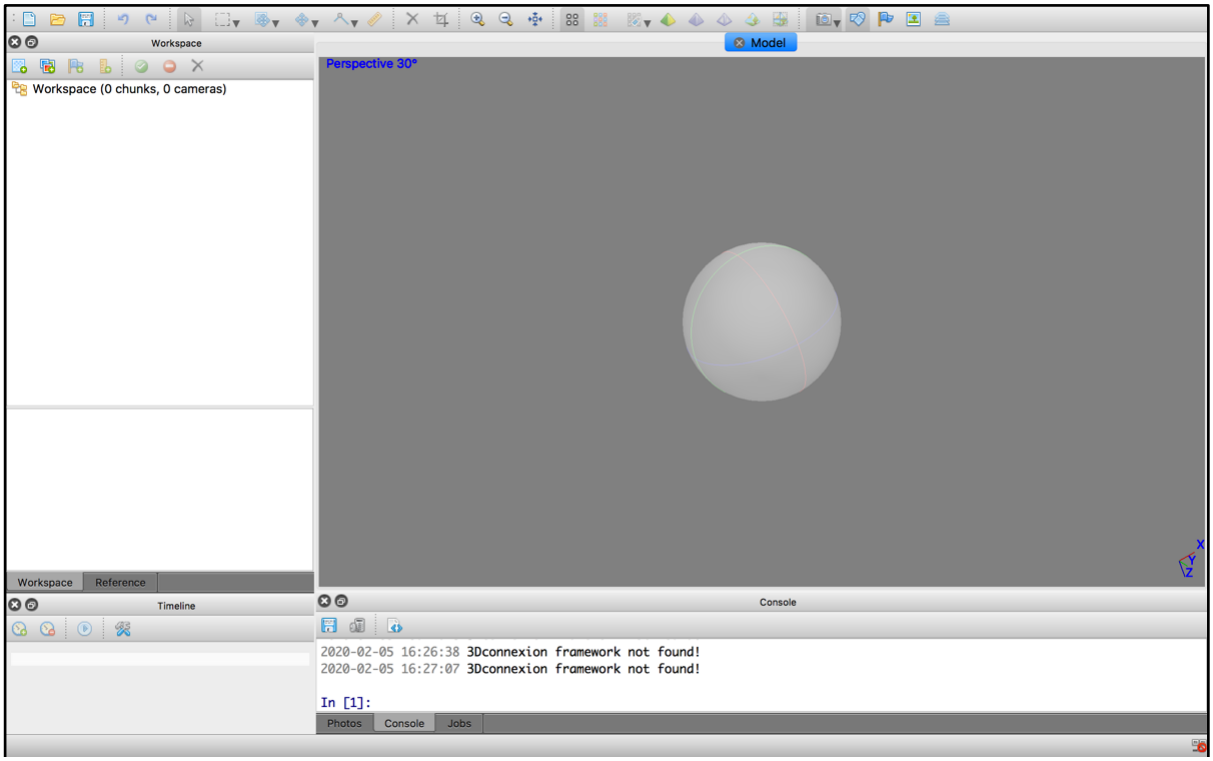
My time at Cherish offices in Dublin and Aberystwyth was primarily spent attending to the secondary processing of datasets derived through either UAV survey or laser scanning. While certainly different, the two approaches are also quite comparable in terms of how their processing is sequenced and performed. At the time of my fieldwork, both partners of the project were using a standardised guide for photogrammetry developed by the Discovery Programme. However, they had yet to develop a similar document for processing laser scanning surveys (although this is an ongoing objective within the project). Observing the processing and visualisation of data from either type of survey, it became clear that the standardised formalisation of their collective approach to photogrammetry had clearly

influenced their individual approaches to the processing of laser scanning data. As such, it is worth first broadly addressing photogrammetry, particularly how photogrammetry software has influenced the visualisation of Cherish data more generally.

Practitioners at both the Discovery Programme and the Royal Commission execute their respective photogrammetric projects using the Agisoft photogrammetry application *Photoscan*. Much as ESRI's suite of GIS platforms (ArcMap, ArcScene, ArcGIS online, etc.) have become synonymous with the GIS profession in general, "Photoscan" has long served as something as an industry standard for 3D modelers of all stripes. It is a remarkably user-friendly programme with a designed interface that would be recognisable to anyone familiar with other spatial data analysis tools (see; ArcGIS, QGIS, AutoCad, etc.) (*figure 5.1*). By simply working one's way sequentially through the steps gathered under the drop-down menu "Workflow" and following the prescribed recommendations of the dialog boxes initiated at each step, a beginner—such as myself—could produce a competent and cohesive 3D object[49] in less than an hour[50]. It is also remarkably powerful, and the practiced or professional user can dig much deeper to configure the software to perform a range of intricate and dynamic tasks.

[49] One of my earliest experiments with Photoscan Pro was a model I produced of "The King's Stone", a neolithic/Bronze Age monument and one of Oxfordshire's famous "Rollright Stones". I'd hiked to the Rollrights late in the summer of 2018 and—finding the site relatively abandoned—performed a series of 20 photographs with my iPhone around the circumference of the monolith. After uploading these photos into the software, I worked through the prescribed steps of photo alignment/sparse cloud construction, dense cloud construction, decimation/meshing, and texturing (as detailed in figures 3.1-3.5). I then exported the final product to my Sketchfab profile (https://skfb.ly/6Q8CN). I was struck by the detail of the resulting model, particularly given the somewhat restrictive file-size limitations imposed by the Sketchfab platform (50MB/upload). Excluding a small selection of voids generated by the blind spots missed by my photography (almost all on the top of the stone), I could spin the model around and zoom in on the striking clarity of the feature's divots and lichen cultures.

[50] The time it takes to produce 3D models, it should be mentioned, is remarkably variant and entirely bound up in the size of the datasets being worked upon and the tasks a user queues the software to execute. My early Photoscan experiments, for example, were largely composed of image caches composed of 30 or so photographs at the most. Working my way through these first attempts, I also opted to optimise each processing function to be the least time expensive, ultimately producing low resolution work.



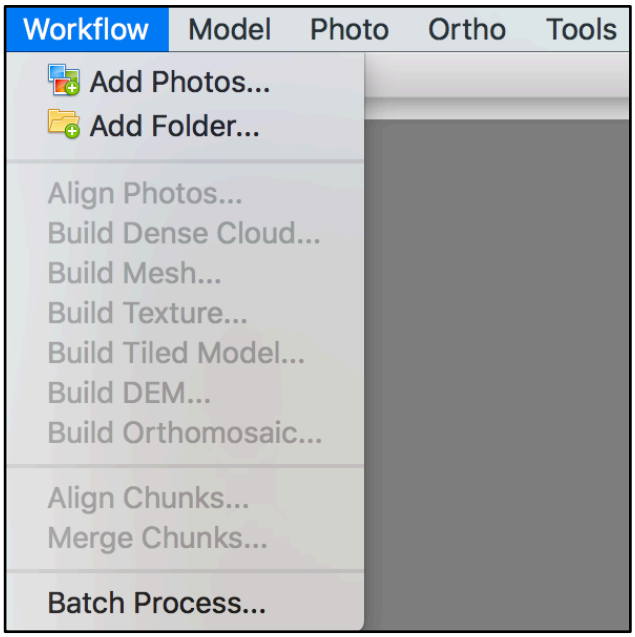


Figure 5.1. *(Top image) a screen grab of the opening layout for Agisoft Photoscan Data is visualised around xyz axes emanating from the center of the grey sphere. As files are added and developed they are saved as "layers" in the left hand column. Here the user can select versions of the model at its iterative stages to be visualised. The icon bar at the top of the screen includes short cuts to editing tools and further visualisation options. The bottom space of the layout, labelled "console", documents a running script log of the operations as they occur in real time. In the event of errors and snags, users can read through the script to locate and troubleshoot issues. (Bottom image) a screen grab of the "workflow" drop-down menu. After adding images and files the user works can work through from "Align Photos" to "Build Texture" in sequence and easily produce cohesive models. Source: screen grabs by author.*

As mentioned above, Cherish practitioners undertake photogrammetric modelling and visualisation in accordance with a standardised guide shared between the individual Cherish research entities. Initially drafted in 2017 by a student in residence at the Discovery Programme, the "Agisoft Photoscan—UAV Processing Workflow" document (*see appendix II*) remains a work in progress. Iteratively updated and refined, it tangibly reflects something of the Cherish partners' larger goal of deriving a protocol of best practice for modelling (and monitoring) heritage landscapes. And while this document is prescriptive for the practice of photogrammetry only, the sequence and workflow it mandates bears significant similarity to the steps undertaken in the task of rendering data acquired through laser scanning and walkover survey as well. In each context, the data acquired in the field is submitted to roughly the same process: the image-based data are first uploaded into the appropriate interface(s)[51]; these data are then geo-rectified in relation to both the coordinate-based data acquired in the field *and* the *abstract* coordinate-based spaces calibrated within the software[52]; from here—via varying processes of both elaboration and reduction—the data gradually cohere into digital objects. This chapter, then, is (loosely) organised around the sequential and mandated protocol laid out in the aforementioned photogrammetry guide. Doing so enables us to not only observe the relationship between various datasets at various stages, but to track when and where they cohere and fit together as they come to constitute something new. This chapter will also address what happens when these datasets do not fit together, or when projects encounter snags and problems. Such instances still resolve in the coherence of digital objects of a sort, albeit objects without any explicit use or function in later contexts.

[51] Certain tasks, described herein, may require multiple programmes in order to be executed.
[52] As will be evidenced later, the coordinate systems that define these workspaces are configurable to different standards and case-to-case needs.

Travelling with the Cherish data from the field to the office, I attended to these secondary stages of processing through similar means of observation and semi-structured interviews. In both Ireland and Wales, practitioners like Robert, Daniel, and Louise guided me through their respective approaches as they processed and rendered the datasets I had observed them acquiring in the field. In attending to these processes—specifically to how the spatial registers produced through acquisition were translated, re-articulated, or re-inscribed into the data as it moved across interfaces or was worked upon in-software—new configurations of instruments, tools, protocol, and expertise also materialised. The evolution of the data from this point forward is contingent upon both what had already been inscribed into it (i.e., situated knowledges and spatial registers produced through acquisition), as well as the new spaces and situations which emerge through the performed practice of processing and visualisation. Each iterative procedure gathered at this stage was seen to resolve in increasingly discrete and organised datasets. As such ─ and particularly in anticipation of the next chapter's discussions of digital heritage objects ─ this chapter focuses on these processes of object *coherence*.

5.3 Steps 1-4: set-up, importing data, image coordinates, and "photo-alignment"

To demonstrate, we will begin with the first stages of the prescribed photogrammetry workflow. Here, data is ported from the instruments and SD cards where the acquired survey data is initially stored. In following the first four steps laid out in the photogrammetry protocol document, this section addresses how the coordinate-based and visual datasets acquired in the field (in either UAV survey or laser scanning) first come to be processed together and eventually integrated with one another. Furthermore, attending to these initial stages also evidences how the integration of these datasets enables caches of two-dimensional images to be organised within a three-dimensional space. As such, these initial four steps also

indicate how the spatial registers produced in the field and inscribed in the resulting data come to determine new spatialities produced by these steps and procedures. By specifically attending to the initial processing of coordinate-based and visual datasets together, this chapter explicitly addresses how the processual cohesion of digital objects and their attendant spatialities are mutually generative; a discussion which underscores how the visualisation of digital heritage objects is inextricably bound up in with articulations of location, position, and accuracy.

After two days spent in Pembrokeshire acquiring data at both Nab Head and Carfai (UAV survey and hachure drawing, respectively), I returned to Aberystwyth with Daniel Hunt to begin the secondary stages of working with the data. We began with the cache of drone-images that Toby had collected at Nab Head. Here, the images were transferred from SD cards onto the database server the Royal Commission has established specifically for Cherish work. The server houses a complex file directory organised first by "site", then by survey method, data type, and the iterative stages to which models had been rendered (Chapter 6 of this thesis explicitly discusses the structuring Cherish's databases)[53]. Clicking through to Nab Head's parent folder, Daniel created two separate folders for the images Toby had acquired with the drone: one titled "Raw Images", the other "Working Photos". Both housed identical datasets. The raw images, once uploaded, immediately become subsumed into the project's gradually accumulating data legacy[54]. The working photos, by contrast, serve as the basis from which photogrammetry can begin. Already, then, the field data has undergone a significant transformation; it has been doubled and bifurcated into twin datasets, primarily as a means to preserve this raw and unprocessed set for posterity. This practice also signals something of Daniel's awareness of both how significantly the data will change

[53] The project's choice to partially organise its databases around concept of "sites" is yet another indication of the unproblematic or self-evident manner they spatialise sites of acquisition.
[54] More on this in Chapter 6.

moving forward, as well as the potential benefit of future users being able to perform their own interventions and investigations of the "original" dataset.

From here the working photos are uploaded into Adobe Bridge, a software which primarily functions to render the entire photographic datasets as contact sheets. Within Bridge, Daniel is able to work with the metadata for the entire dataset, ensuring that semantic information attached to the image cache—such as naming conventions, dates and times, etc.—are consistent and appropriately distributed across the dataset[55]. Daniel also uses Bridge to inspect the quality of the photos he plans to port over to Photoscan, looking for aberrant or inconsistent outliers. I observed Robert using Bridge to perform similar quality control overviews of the images brought back from both Dun an Oir and Dunbeg Fort. The oblique images, Robert explained, are of slightly higher quality compared to their orthogonal counterparts, primarily because automating photography via the Groundstation mapping interface requires the images being captured while the drone is in motion. The oblique images, by contrast, were captured almost entirely under Robert's control and from positions of (relatively) static location. The consequence of all this, and the reason both Robert and Daniel spend the time combing through their data before sending it to Photoscan, is that the individual images have to be legible to the software; specifically, because the very principle of photogrammetric modelling is based on the software's capacity to effectively associate and correlate numerous images with one another. And while the differences in quality between the two datasets are usually negligible, the variant conditions produced through processes of acquisition correlate to how, and how well, a given dataset can be combined and visualised *together*.

[55] Consistency is important in this regard as softwares use file names as a means to sequentially process their inputs as they "align" uploaded image caches.

Once the dataset has been evaluated and cleaned where necessary, it is then uploaded into Photoscan in batches; first the overheads, then obliques[56]. This requires organizing the data in relation to a specific cartographic framework or grid. Before submitting the uploaded data for "photo-alignment"—the process through which a "sparse" point cloud is first derived—Cherish protocol mandates the calibration of the parent coordinate system of Photoscan's digital workspace. The software defaults to WGS 84 (World Geodetic System) as a basic means for organising inputted data but can be further configured to map projections that best fit with the data acquired. For Robert, and all the data gathered in Ireland, this means configuring the workspace to the Irish Transverse Mercator projection. For Daniel and the data acquired in Wales, this means setting the coordinate system to British National Grid (Ordnance Survey projection OSGB70). It should be noted that the perceptible difference between models assembled from the same input data, yet within different map projections, would be negligible. The difference, however, would be in the resulting model's capacity to be contrasted and/or analysed with other datasets models registered to different map projections. In both contexts, any adjustment to the parent coordinate system (from WGS84 to ITM, etc.) indicates how the "abstract", or geo-referenced spaces of the interface must correspond to the virtual/abstract spatial registers produced in the field (via Virtual Base-Stations or Real Time Kinetic networks used to calibrate GNSS antennas, for example).

In the "photo alignment" stage, Photoscan takes the respective eastings, northings, and elevation measurements for each inputted image (embedded within the metadata for each file) and plots them within this configured coordinate system. The coordinates native to each image are derived from the internal GPS readings generated by the drone, which, while imprecise, are nevertheless capable of approximately situating each individual photo in the

[56] While it rarely occurs, unusable photos are occasionally omitted from the caches submitted to alignment. This omission, however, only impacts the collection practitioners designate as "working photos". All the survey photos ― including those they deem problematic ― are saved in the "raw" photos collection.

digital workspace in relationship to "where" they were taken in the field (*figure 5.2*) [57]. What's at play here, then, is a unique fitting-together of an abstract spatial register (the calibrated coordinate system) and an *inscribed* one (the coordinates derived from both the drone and the initial performance of acquisition):

> The drone, well…when you import the photographs from the drone they have already got the geo-tagged info, but with errors of metres. So, when you import them the dots will actually appear and you will think, "*oh bloody hell! it's actually figured out where they are*", because it already has an idea of where it was. But obviously that is not good enough for what we use these for—which is why we bring the ground control. It brings in WGS and you've got to transform that into [the] British National Grid. And over in Ireland it would be, it is the Irish Traverse Mercator (Daniel Hunt, Interview, 25/03/2019)

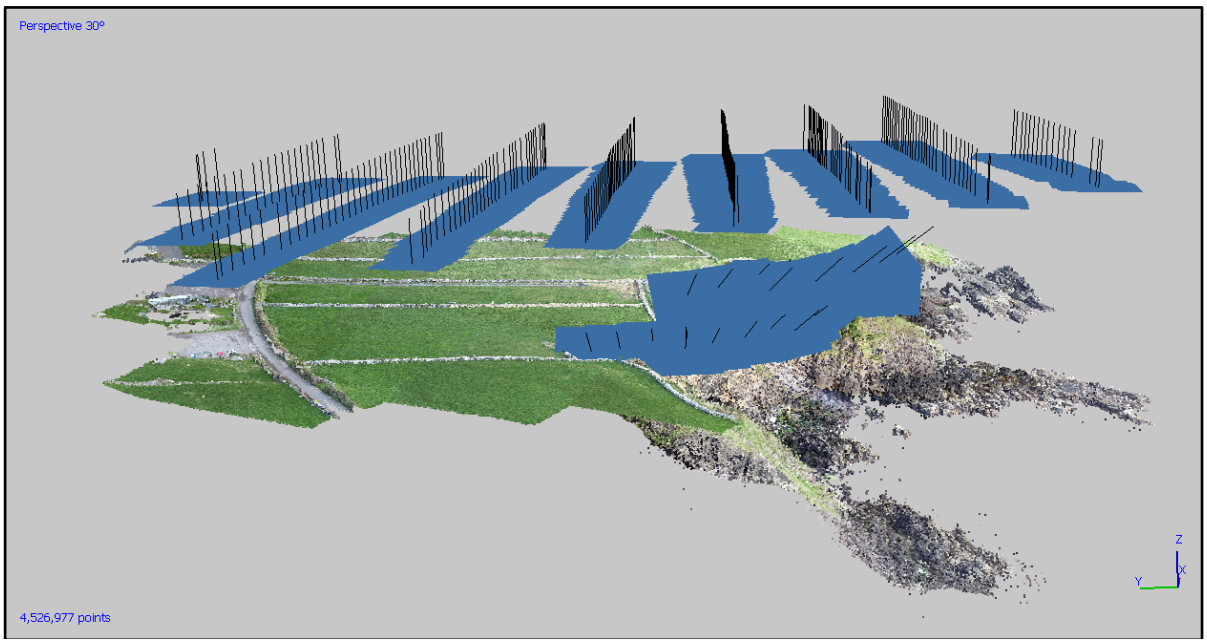
In establishing a parent map projection (such as the British National grid, or the Irish Transverse Mercator projection) for the entire digital workspace, Cherish practitioners ensure that the imported imagery can not only be translated as a cohesive three-dimensional form, but one which can be analysed in reference to other cartographic products and materials. The error in metres which Daniel mentions above does not pertain to the inputted data's capacity to cohere as an object, but their capacity to be relationally compared to geo-referenced datasets from outside a given modelling project. As such, the coordinate-based data inscribed in each individual image are subjected to further processes of refinement in order to ensure this, as indicated by Daniel's mention of bringing in ground control at later stages (which will be explicitly discussed in the following section).

Before doing so, however, a series of operations are run in order to derive shared features from the entire image cache. The images are processed against one another in order to derive first what are known as "key-points"[58] (significant/identifiable features normally

[57] Primarily owing to both the fact that a.) the camera within the drone is not recording the photographs in accordance with a configured map projection and b.) the inherent measurements are unreliable on account of the fact that the elevation is measured from the drone itself as it moves between altitudes.
[58] Key points are shared 2D points located across the selection of images submitted to processing. Key points are selected on the basis of the size of the images submitted and the visual content of such images.

selected on the basis of texture or contrast). The software then processes selected key-points to derive "tie-points"[59], which are produced via the pixel matching of image-to-image comparison, with shared features located across two or more photos being extracted as points. Taken in the aggregate, these points come to comprise a "sparse cloud" *(figure 5.3)*. For the dataset collected at Dunbeg Fort—which was comprised of 256 images (both overheads and obliques)—the photo-alignment resolved in a sparse cloud of 4,147,093 tie-points. Demoing some early modelling he had been doing of Dinas Dinlle, by comparison, Daniel submitted some 1080 photos to alignment, returning a sparse cloud of 3,600,000 tie-points. The non-proportionality between the images and sparse clouds inherent to both projects is reflective not only the area of the headlands being digitised (Dinas Dinlle is in fact much larger than Dunbeg), but the difference of how photography was performed in the field. Data submitted from laser scanning projects, by contrast, arrive in the software as separate scan jobs, each with their own corresponding, already existing, point clouds. The work of preparing these datasets for further refinement, then, requires stitching these individual scans and clouds together. Before importing the individual scan jobs from the hardware to the first of several pieces of software used in this process[60], the digital workspace within the software is likewise first calibrated to the appropriate map projections. Much as the image caches ported over in photogrammetric projects rely on the GPS native to the drone to be situated, the orientation of the scan data within the calibrated coordinate-system of the interface is determined by virtue of the scanner's internal inclinometer[61]. And while there is no direct analog for the "photo-alignment" stage performed in photogrammetry, the initial fitting together of disparate datasets is determined through a process known as "cloud to

[59] Tie points are 3D points (derived from corresponding key points) which the software detects, computes, and plots within the digital workspace of the photogrammetry interface. It is these tie points which compose both the sparse and dense point clouds of photogrammetry projects.
[60] Namely, FaroScene, a proprietary programme that comes with the scanner.
[61] For example, the scanner itself has the internal capacity to determine cardinal direction, what is up, down, etc.



Figures 5.2. *A screen grab of the aligned images and the resulting sparse cloud they produce for the survey I observed at Dunbeg Fort in April 2019. Each of the blue tiles either above or around the sparse cloud represent the individual images taken by the drone. The more regularly segmented tiles directly above the model are those taken by the drone during its programmed flights using groundstation. The tiles obscuring parts of the cloud in the bottom righthand corner are those Robert manually piloted.*

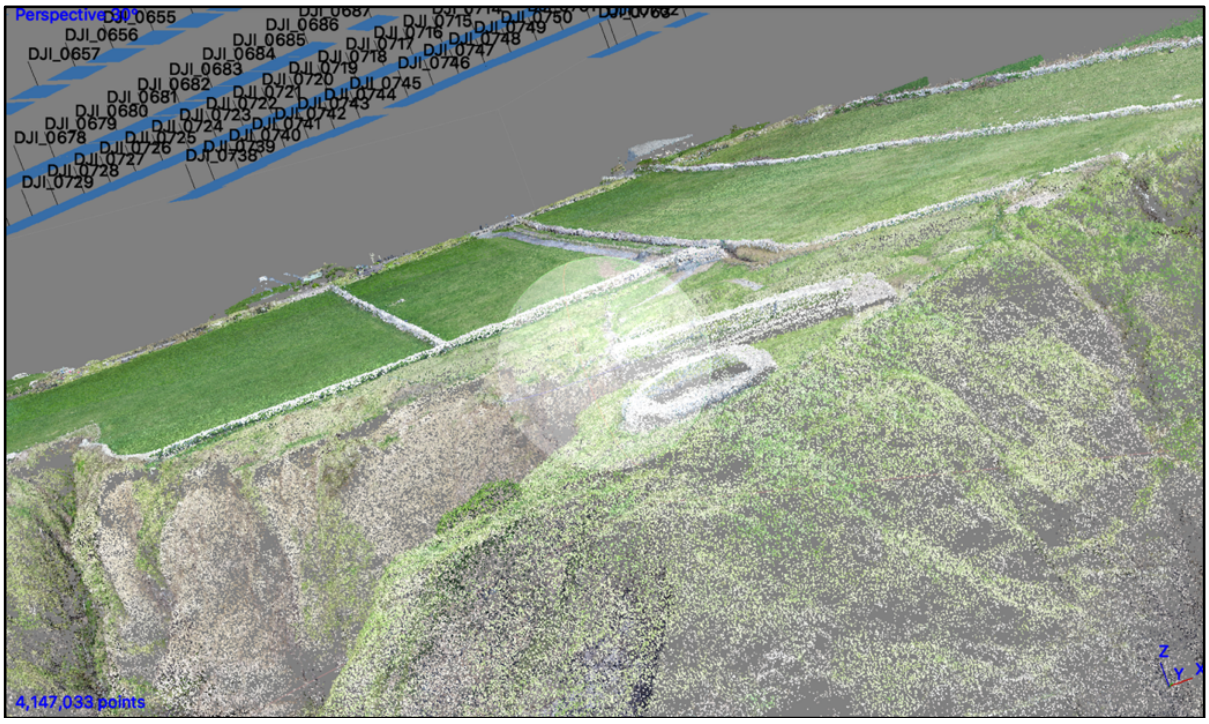


Figure 5.3. *A screen grab detailing the resulting sparse cloud after alignment. As indicated in the bottom left-hand corner of the image, the cloud is composed of 4,147,093 points. A number which, despite the appearance of cohesion at this stage will be dramatically elaborated once processed as a dense cloud. Source: screen grabs by Robert Shaw.*

cloud registration[62]". Here, one of the several scans composing the project is selected as the "reference scan", or the scan from which the relationship between all the other scans will be determined. Reference scans are commonly chosen on the basis of having the most registration spheres visible within their respective clouds. Often they directly correlate to the first scan taken in the field, but not always. From here, the remaining individual scans are submitted to a process whereby the spheres in each of the remaining input datasets are located and identified.

The ease with which this process is performed is largely dictated by the method of acquisition exercised in the field. As outlined in the preceding chapter, the emphasis and importance Robert placed on visualising a project ahead of its acquisition, and in performing the scanning in such as manner as to produce a "closed traverse", pertains specifically to the anticipated success with which FaroScene is able to correlate the inputted scans. The issue, then, is one of integration, of ensuring that the individual scans relate to one another on the basis of their shared points of reference. Integration, then, is predicated on the re-constitution of field measurements within the digital workspace, all towards the objective of constructing a cohesive geometric feature from the initial measurements and scans:

> Yeah, so what it is basically saying is…it's allowing it [the software] to account for the fact that you will get a nice [output] at the end of the process, and it's saying that I've got an approximate position. I can just shuffle on at this time, I can work on the positions, the geometries, because you do one at the time. But at the end of the process there is an overall geometry because you've closed back on something. Surveying experience tells me that if I don't do that I am going to end up with the potential for a traverse to hinge, as it were. Each component is a bit like a chain…you could propagate the error along. So if they're all a little bit out as they go along, by the time you compare the end to the beginning one it could be quite significant. So you have to be quite careful about that. In surveying one of the first things you learn is sort of that open traverses is a hazardous way to work. Every time you make an error that can propagate to the next part. The only way to avoid it going on is to close back (Robert Shaw, Interview, 28/05/2019).

[62] Unlike the protocol document used in photogrammetry, there is no official workflow manual used by Cherish practitioners for laser scanning projects, though each of the individuals interview contended that there likely should be.

Despite being just the initial derivation of points, these resulting clouds—in either photogrammetric or scan-based visualisation—often appear remarkably vivid and cohesive (see figure 5.3). Yet their function at this stage is strictly to provide practitioners like Robert and Daniel with the means to assess how well the data is fitting together. Regardless of how they might appear, their use (in analysis, for example) is limited until they are geo-rectified to the control points taken in the field and further processed. As a result, these initial stages of translation are primarily defined as just the first of many. Travelling from the respective field-instruments that facilitated their initial capture and in moving between and across platforms of visualisation, the data acquired in the field (visual or otherwise) is first fundamentally changed by the very act of moving from one software to another. With any sequence of digital information (be it a script of code or a JPEG file), the "porting" of data is "always an act of translation and adaptation", one which simultaneously indicates not only how data are capable of being expressed, but also of the "many ways it might have been other than what it is" (Montfort, 2013, pg. 61). The translations at these earliest stages are first calibrated to reference and reassemble the spatial registers produced through acquisition (via the synching of map projections, or the deliberate sequencing of scan registration, for example). Deciphering what, exactly, is translated is complicated by how we understand the knowledges inscribed into primary acquisition data as being *situated,* and how we understand such datasets as being *mutable*. As these translations of data accumulate throughout a given workflow, some inscriptions carry over from step to step (i.e., they are reduplicated in the metadata schemes of the outputs), and some are no longer present in such outputs.

Much as Gillian Rose has used the devices of *interfaces*, *networks*, and *frictions* as a means to establish "*mutability*" as an inherent characteristic of digital cultural objects, the derivation of sparse clouds in these initial stages of visualisation and processing ─ and the processes of *translation* this research locates therein ─ can be understood in similar terms

(Rose, 2016a). In attending to relationship between spatial registers produced and translated across sites of acquisition and processing (*networks*), the impact or influence specific softwares/platforms have on given datasets (*interfaces*), and the productive *intra-action* between practitioners, data, softwares, and interfaces (*frictions*), the cohesion of Cherish models as digital objects can likewise be defined in terms of mutability. Furthermore, these processes of cohesion engender a pronounced distance between the models being produced and the events and processes from which they are principally derived. Digital images—and, by extension, digital visualisations more generally—both "break the temporal link between record and event" and "challenge photorealism's conflation of truth and reality" (Chun, 2011, pg. 15). After Latour, however, it is the relationships between each of these iterative steps and processes that compose the system of circulating reference which enable the abstraction of a "record" (i.e., a digital heritage object) from an "event" (i.e., the acquisition of data at field sites). As such, the cohesion of Cherish data as digital objects is defined and constituted as much by these assembled sites of processing as they are by the headlands or features they ultimately depict.

Before advancing to the subsequent stages of the Cherish protocol document, however, there is an imperative to discuss the conceptual relationship between the cohesion of digital objects and their respective enframing within gridded, coordinate-based, geometries. As the previous chapter has established, the acquisition of Cherish data produces distinct spatialities, the iterative translations of which this chapter links to the processual coherence of survey data as digital objects. Yet the tendency to frame the relationship between spaces produced and objects rendered as occurring in either strictly sequential or linear-based ways should be resisted. For just as the enactment of spatialities produces objects, the derivation of digital objects produces distinct spatialities. John Law, for one, has

contended not only that spatialities are inherently enacted, but that the derivation of objects in "network terms"—such as the contextual framing of Actor Network Theory, for example—"is not spatially neutral, but also implies the production of a particular kind of space" (Law, 2002, pg. 94). Law uses the Portuguese shipping networks in the sixteenth century to illustrate; a transatlantic shipping vessel, while fundamentally constituted in part by what he lays out as "Euclidean" or coordinate-based space, is not defined only by such space. It is also defined by the cohesion of the "networks" (and their associated spatialities), such the networks of international commerce and trade such vessels are situated within. In defining objects as "intersections between homeomorphic enactments produced within different topologies", Law discusses the production of both objects and spaces as being mutually generative and thoroughly heterogenous (Law, 2002, pg. 96). Law's example of Portuguese shipping also appears in *Situating Technoscience: An Inquiry into Spatialities* (2001), a piece co-authored with Annemarie Mol. Here, the illustrative device is used to explore the notion of the "immutable mobile"—i.e., the characteristic of a given object to sustain its cohesion through motion and transformations—specifically how "Euclidean space" functions in relation to an object's perceived immutability:

> …the immutable mobile achieves its character by virtue of participation in two spaces: it participates in both network and Euclidean space. And such is Latour's trick. To talk of an 'immutable mobile' is to elide the two. The immutability belongs to network space: to a first approximation the vessel does not move within this. If it did, it would stop being a vessel. But it is that immutability in network space which affords both the immutability and the mobility in Euclidean space. To put it more strongly, it is the interference between the spatial systems that affords the vessel its special properties. We are in the presence of two topological systems, two ways of performing space. And the two are being linked together (Law and Mol, 2001, pg. 612).

The relationship Law and Mol trace between Euclidean and Network spaces is particularly interesting to consider within the context of the Cherish workflow for rendering 3D digital heritage sites. The "Euclidean" space(s) inherent to the derivation of 3D digital

objects is likewise configurable within, and responsive, to the "networks" (or assemblages) likewise seen to comprise a digital object. Software like Photoscan/Metashape, FaroScene, or RealWorks not only constitute part of the socio-technical assemblages that produce what Law and Mol would define as the "network" space inherent in Cherish's digital objects, but they are also the primary means through which "Euclidean" or coordinate-based space is meted out and articulated. In order to better decipher how the distinct configuration of coordinate-based space within the software is both generative of, and generated from, the digital objects being assembled, one must consider how such space is both produced through the performed enactment of Cherish practitioners *and* fundamentally responsive to the affordances or limitations embedded in a given software. Most every software is designed to function in accordance with prescribed or expected use. Much as Light et al. suggest the technological features of a given software have distinct affordances, programmes like Photoscan—by virtue of how its workflow is designed—produces specific conditions from which practitioners (in collaboration with the softwares and tools at their disposal) can enact spatialities and refine digital objects (Light et al., 2017).

This still leaves some room for improvisation within the interface, however. Cherish practitioners have each developed their own methods for working both within and outside of software protocols. In a manner reminiscent of what Malcolm McCullough has described as "digital craft", Daniel, Robert, and Aaron each exhibit their own means of both applying "standard technological means to unanticipated or indescribable ends" or using "limited software capacities resourcefully, imaginatively, and in compensation for the inadequacies of prepackaged, hard-coded operations" (McCullough, 1996, pg. 21). All this becomes particularly evident in attending to the stages of the Cherish modelling protocol immediately following photo alignment. In the translation of "control targets"—and the abstracted networks of reference they comprise—into Photoscan's digital workspace, for example,

Robert demonstrated approaches and techniques that were both innovative and occasionally not outlined in the Agisoft processing manual. The stages of "Sparse Cloud Cleaning", by contrast, provided insight into instances where Daniel or Robert submitted data and projects to the black-boxed functionality of the software without entirely being able to explain how the software worked. Moving through the Cherish workflow document ─ from photo alignment to control targets and the cleaning of sparse clouds ─ helps to elaborate the role softwares like Photoscan[63] play in the socio-technical assemblages of the Cherish workflow. Doing so also highlights the situated enactment performed by practitioners as being directly co-constitutive of both the spaces and objects produced throughout these processes.

5.4 Step 5: distributing "control"

As detailed in the previous chapter on data acquisition, the placement and registration of control targets across a landscape was one of the more time-consuming and detailed procedures observed in the field. Walking from target to target, using a GNSS antenna to register coordinate-based locative measurements, Cherish practitioners sketch an intersecting framework of boundaries, which is ultimately purposed in secondary stages of visualisation and rendering to geo-rectify the resulting point clouds. Deploying control targets within a sparse cloud begins with gathering a series of reference materials produced in the field. Both visual and non-visual, these materials are principally composed of both the coordinate data acquired through the Trimble GNSS antenna at the locations where the physical targets were registered, as well as the photographs taken of these physical locations. The coordinate data are exported off the antenna as a CSV file[64] and are comprised of a simple table of attributes. Here each target is coded with a name (T1—Tn for the control targets, R1—Rn for the stable

[63] Or FaroScene, RealWorks, etc.
[64] Comma separated value files, basically the generic version of what one would export from Microsoft Excel.

reference features recorded in order to retrofit previous models of Dunbeg, for example), as well as values for easting, northing, and elevation[65]. The work of deploying control within the model requires finding the targets within the photographs that have already been uploaded into the software. At this stage in the process, Photoscan can visualise both the sparse point cloud and the respective "positions" of the photos from which the cloud was derived. As such, finding the images of the targets requires first navigating the modelled landscape in its sparse cloud form and searching through the images gathered in the vicinity of areas of interest (*figures 5.4 & 5.5*). Matching the correct coordinates with the correct images of the targets, however, is often complicated by the fact that the code names emblazoned on the physical placards used in the field are commonly not identifiable within the images returned from the drone.

This, in turn, requires consulting the supplementary images Robert or Daniel have produced in the field of the targets as they were being registered. Collectively, then, the process requires pinging between three distinct visual sets of data: the sparse cloud, the images from which the sparse cloud was derived, and the supplementary field photographs. For the work I observed being done on the datasets acquired at both Dunbeg Fort and Dun an Oir, Robert demonstrated one of the principal innovations he employs in improving his approach beyond what is provided within the software; namely, the generation of a 2D cartographic product from which the navigation of these three datasets can be more easily integrated (*figure 5.6*). Sending the coordinate data to ArcMap, Robert produced a simple map indicating where in the landscape the original targets had been deployed and where, by extension, we might begin looking in the cloud. Crucial, however, was the degree to which

[65] The first value on any of the CSV files I saw was always a coordinate registered from either the virtual reference station or the basestation of the RTK network used in the field. Because these values don't directly pertain to the distribution of control being established within the model, they are often deleted from the table before the process really begins. As such, there is a way in which the erasure of this particular coordinate—initially so crucial to the abstraction of the spatial network now being deployed—evidences the first of many processes wherein specific information (spatial or otherwise) is *not* translated into the digital/virtual context.

190404_dunbeg

PRS509142198255	459459.908	601409.830	37.898
dunbeg1-109	434959.788	597427.342	39.946
dunbeg2-103	434925.651	597508.134	51.606
dunbeg3-114	434981.412	597527.699	51.490
dunbeg4-101	435019.792	597459.755	42.015
dunbeg5-111	435059.100	597381.464	33.036
dunbeg6-119	435006.796	597407.519	36.666
dunbeg7-112	434998.744	597370.123	33.198
dunbeg8-113	435014.259	597342.372	29.274
retro1	435005.303	597332.796	28.473
retro2	435007.822	597348.736	29.578
retro3	435030.559	597358.754	30.719
retro4	435009.238	597359.722	31.287
retro5	434997.067	597370.970	33.087
retro6	435034.482	597376.351	32.770
retro7	435009.857	597383.380	33.985
retro8	434993.250	597394.234	34.732
retro9	435016.251	597354.566	32.197
retro10	434969.479	597400.005	37.048
dunbeg9-102	434861.459	597477.627	52.104
dunbeg10-100	434912.628	597416.589	40.513



Figures 5.4. *(Top left) a CSV table of control target coordinates taken at Dunbeg Fort on April 4, 2019. The first column in this table indicates the code names for the corresponding coordinates. Codes "Dunbeg1-109" through "Dunbeg8-113" correspond to the targets Robert distributed to establish boundaries for the survey. Codes "retro1" through "retro10" correspond to coordinates taken for fixed features at the site that can be used to retrofit previous surveys still requiring geo-rectification. Finally, the last two codes, Dunbeg9-102 and Dunbeg10-100 are the aforementioned "confidence checks" Robert uses to assess the distribution of targets within the sparse cloud. (Top right) is a photo of the target Dunbeg8-113 as the antenna is taking a reading for its location. (l) and photo of target T-113 being registered in the field.*



Figure 5.5. *An orthogonal image taken from the initial drone flights over Dunbeg. The pink arrow points to the location of control target T-113 in the image, illustrating how coordinate information comes to be distributed within the photogrammetry software. Source: top left is a screen grab by Robert Shaw, top right image by author, bottom image by Robert Shaw/DJI Groundstation.*

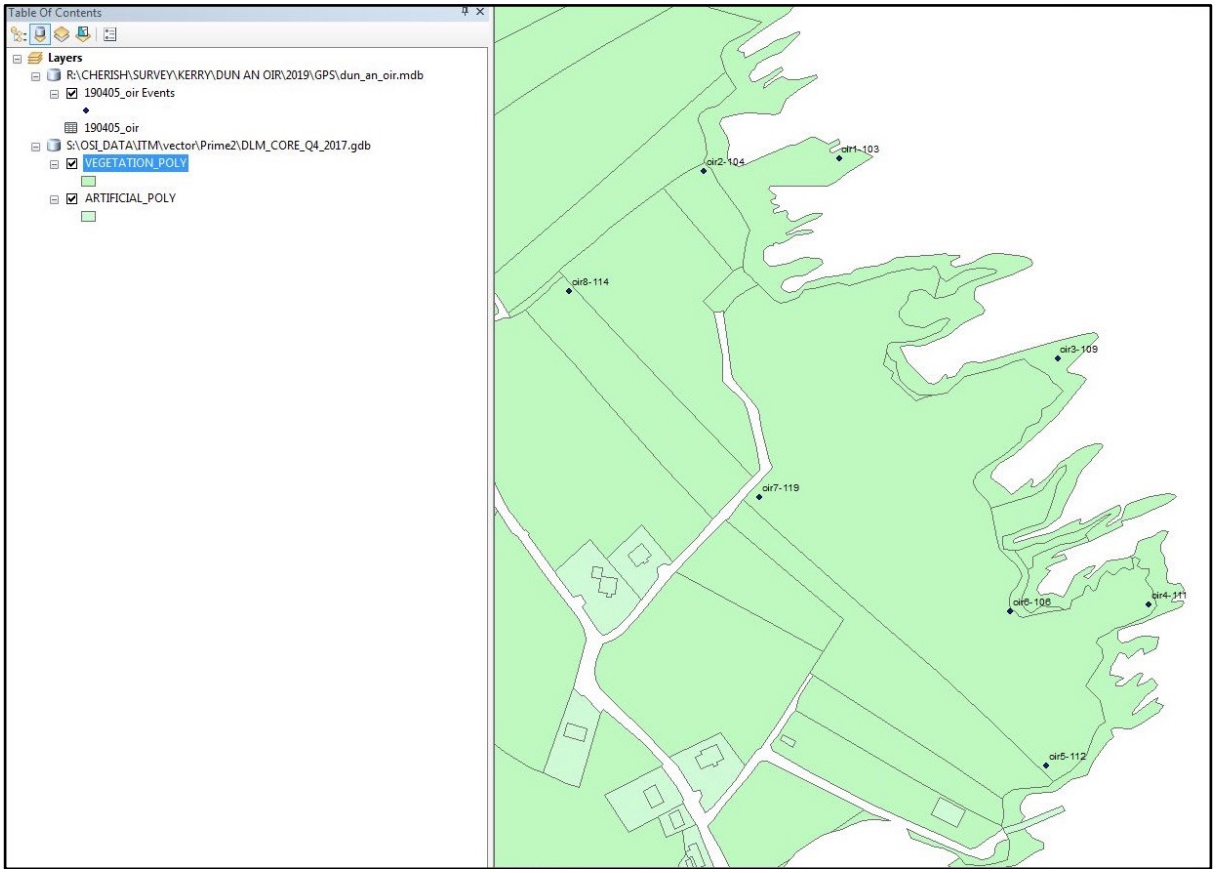
Robert framed the use of this map as a means to reproduce and re-track the original acquisition of control targets in order to re-apply them in the digital context:

> This is where you need to know your sequence…and what can be quite helpful is to sketch out a little map of them, so you remember how you did them, that can be really helpful. Failing that, you can print them out, you can draw [them], you've got the coordinates. You can put them on a GIS map and get the map, that's really helpful too (Robert Shaw, Interview, 27/05/2019).

Navigating this collection of visual tools, then, Cherish practitioners re-trace the steps of their initial acquisition, locating the targets in the appropriate photos and attaching the corresponding coordinates to the appropriate pixels in the digital images (*figure 5.7*)[66]. From here, the software distributes the placed markers across all images with pixel matches, ultimately adjusting the geo-spatial alignment for the entire cloud.

The execution of this process manifests as a reproduction of similar processes enacted in the field during acquisition, not unlike how we had to establish location and position for the antennas and targets within the sites there assembled. What's interesting, however, is the unique asymmetry between the two processes in the context of either acquisition or visualisation. In the field, for instance, position and location had to first be established in order to continue with the acquisition of photographic data. Back at the office, however, the inverse is true; re-applying position or locative grounding to the model/sparse cloud cannot be achieved without first deferring to the photographic evidence already acquired. As such, the relationship between objects and spaces presented by John Law and Annemarie Mol is relevant here. In the gradual cohesion of digital heritage objects neither the derivation of the abstracted spatial reference network produced at sites of acquisition, nor the inter-relationality of the visual data likewise generated and processed, precludes one another.

[66] Like the apparatus of the drone-tablet-and pilot assembled at sites of acquisition, this approach further evidences yet another instance of the digital mediation of embodiment.



Figures 5.6 *A map of Dun An Oir Robert made using the coordinates recording for distributed control target.*

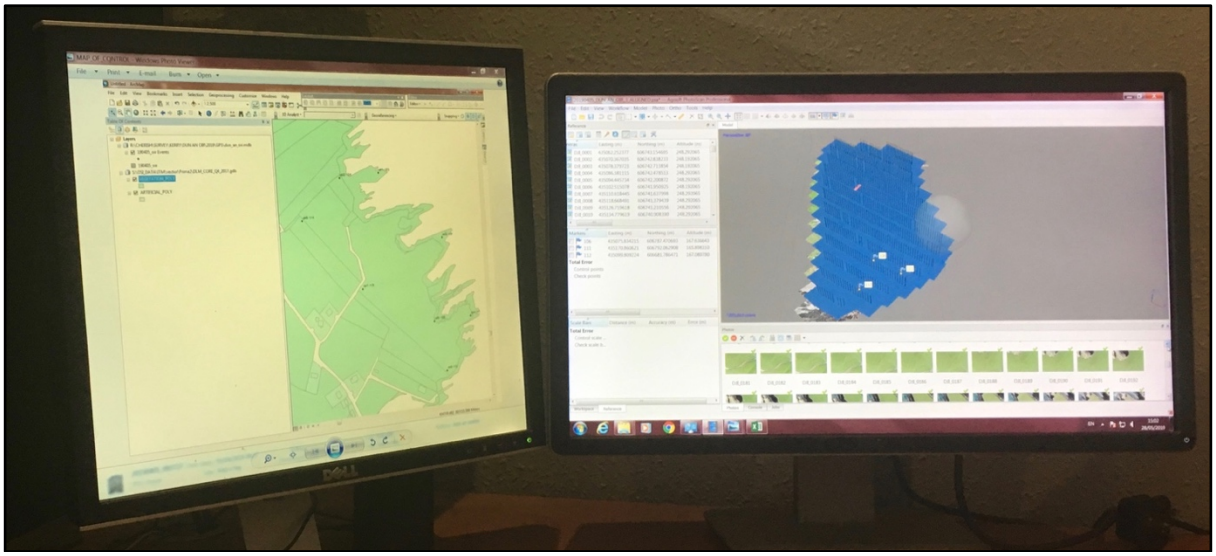


Figure 5.7.*Robert used this map as a reference tool while locating the corresponding control targets within the images and the sparse cloud he had generated on the right-hand monitor. Source: map made using ArcMap by Robert Shaw, photo below by author.*

More accurately, they both refine and define each other as they cohere to form something new.

5.5 Step 6: "cleaning" the sparse clouds

Before a sparse cloud can be more substantially visualised (namely, the generation of the drastically elaborated *dense* clouds, meshing, or further texturing), Cherish practitioners take their sparse clouds—now with control targets distributed—and subject them to a series of operations designed to identify the distribution of error and remove faulty points from the whole. The sequence of operations is as follows:

—*Reconstruction Uncertainty*: the means by which faulty "tie points" are removed.
—*Reprojection Error:* a measure of the accuracy of the points, measured in pixels.
—*Projection Accuracy:* the means by which points having a poorly localised projection are removed.
—Followed by another round of *Reconstruction Uncertainty*.

The Cherish photogrammetry manual provides direction on the tolerances and thresholds to which each operation should be calibrated and, after each operation has run, the practitioner deletes the points selected as faulty or misplaced by the software. After the points have been removed, the "cameras"—i.e., Photoscan's term for the spatially situated individual images from which tie points clouds are derived—are "optimised". The degree to which Robert and Daniel could explain either how the value of the specific thresholds was determined, or what each operation achieved, often varied. When prompted to explain the relative impact of adjusting the tolerance for reconstruction uncertainty, for example, Robert could demonstrate the correspondence between raising and lowering the threshold and the points identified, yet without being able to explain how or why such points were being selected:

> We'll do reconstruction uncertainty—we'll start off with that. So it's analysing the point cloud and now that its analysed it, it will give us a chance to make a decision. And what we do is…if we are happy with a reconstruction uncertainty level of 302—which I'm not quite sure what that value actually means—but it is on this slider, and

> you can see as I improve that value it is starting to select points. If I reduce down to 200, let's say, its selected 11,000 points (Robert Shaw, Interview, 27/05/2019)

Daniel, in his own attempt to sort out the functionality of projection accuracy, similarly struggled to fully account for what the software was actually doing. It was here, in these discussions and demonstrations, that the agencies of the softwares and tools involved in the process were most evident. After DeLanda, it also pointed to one of the distinct ways in which the intra-action between the assembled practitioners, software, and data was generative of "exterior" relationships defined by friction. Simply put, despite these configurations reliably resulting in refined data outputs, the practitioners had difficulty accounting for what about their intra-action with these software components produced the results they sought. And while a practitioner like Daniel occasionally experiments with the thresholds and tolerances prescribed by the Photoscan guide, he admits to closely adhering to protocol because “it just seems to work for what we need it for” (Daniel Hunt, Interview, 25/03/2019).

Throughout the entire process, Daniel and Robert evaluate their work on the basis of both the visual appearance of the sparse cloud and what the software can tell them about the distribution of error within it. Their decision making is primarily based on both the visual distribution of points within the cloud and the statistical information produced as a result of these functions. As a result, then, the process of negotiating these commands and outputs was defined by both a series of aesthetic judgements made on behalf of the practitioner and the prescribed input from the software. All of this is done in anticipation of “dense” cloud construction, the stage which follows cleaning. Dense clouds are produced through similar means as their sparse counterparts, only here the total input is composed of both the original images (now optimised) *as well as* the geo-rectified and cleaned sparse cloud. As the model coheres, however, error propagates throughout the process. The refinement of the points composing the sparse cloud directly affects the individual points in the cloud (*figure 5.8*):

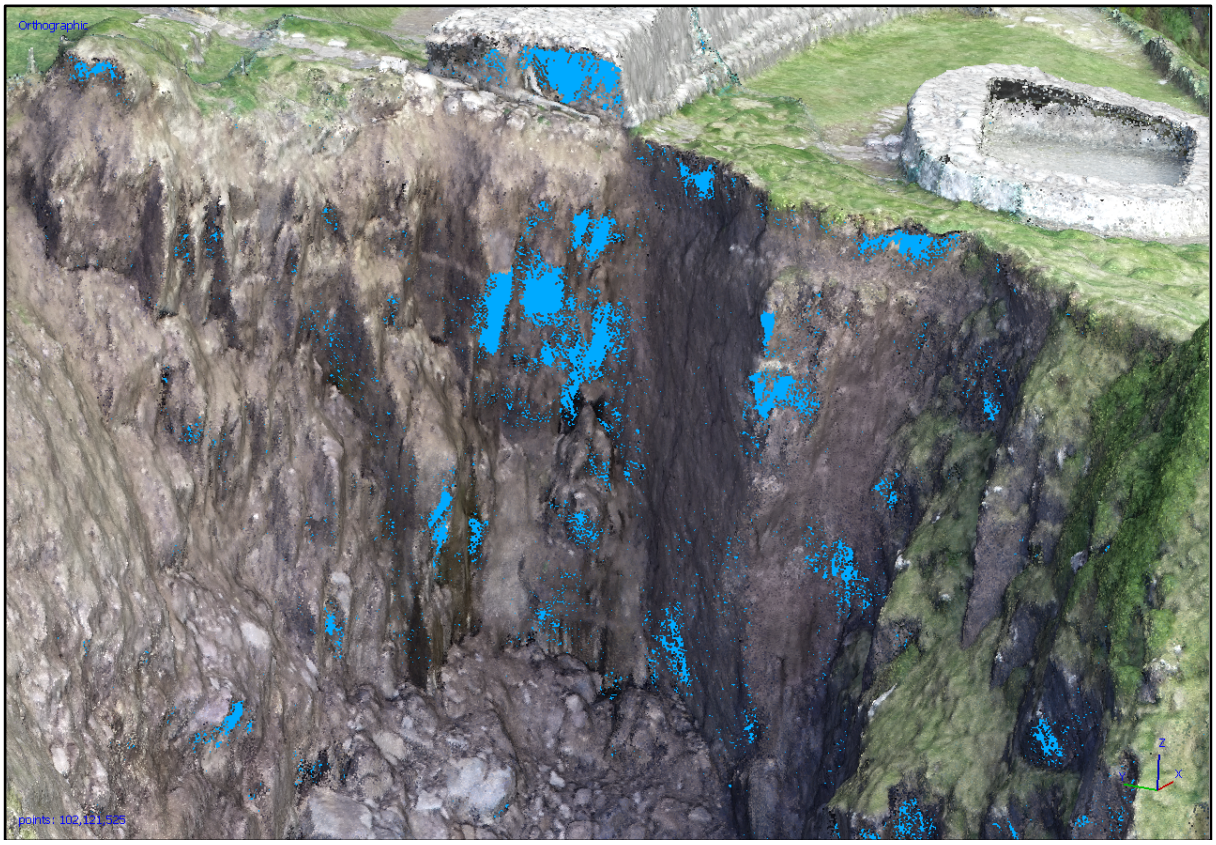


Figure 5.8. *Screen grab detailing a sparse point cloud in the process of being cleaned and optimised. The parts of this cloud shaded in blue are those which Photoscan has identified as being outside the thresholds of error which Robert had configured for the project/model. These points were deleted soon after in an effort to tighten the overall registration of the cloud. Source: model and screen grab by Robert Shaw.*

> The measurement process itself also has an impact on the point itself, especially on the quality of its coordinates and feature values. Positional accuracies for each individual point can be derived in different ways…The precision, or, more generally speaking, the quality, of the coordinates and attributes can therefore be considered as features of each point, as well (Otepka, Guffar, et al., 2013 pg. 1045).

As such, the cohesion of a cloud is not only defined in relation to the coordinate-based space in which it has been constructed and refined, but the cloud becomes a coordinate system itself (Poux et al., 2016).

Because photogrammetric point clouds are derived from digital photographs and elaborated through iterative steps of development, the "cleaning" undertaken at this stage functions to correct and amend the error produced as a result of moving between given software operations. In laser scanning, where the clouds themselves are the primary data, error is not as easily propagated. As such, the points comprising scanned clouds do not need cleaning or optimisation in the same sense. Reducing the distribution of error in point placement, for example, is primarily addressed in the stages of “cloud to cloud registration” covered above. As a result, the closest analog to the “cleaning” performed in photogrammetry is what is known as the “segmentation” of scanned point clouds. This process is more straightforward, less black-boxed, and fundamentally more contingent upon the decision making exercised by a given practitioner. After “cloud to cloud registration” scan data is imported into Trimble RealWorks, a key software for editing scan-derived point clouds. Robert used an older dataset from a scan job at Ferriter’s Castle on the Dingle peninsula to demonstrate the segmentation process.

As a process, "segmentation" is a largely aesthetic exercise primarily centred on the erasure of any evidence of acquisition tools still visible within the cloud. Robert starts with the registration spheres. Having already served their primary function in aligning the individual datasets together, each sphere is encircled and deleted from the cloud and pasted into a parallel workspace opened as another window within the software. The coordinate

system and spatial calibration of this adjacent workspace—which Robert has saved as the "trash" file—is identical to the primary point cloud. As a result, each of the features he removed remained accurately placed and spatially referenced in relation to one another. After each edited feature is pasted into the trash-cloud, the files are merged, producing a cohesive and singular (though visually fragmented) point cloud comprised of the digital refuse. From the spheres, Robert moved to other removing other implements visible within the cloud: the scanner's tripod, bags of kit, jackets and more. Even the presence of visible bodies cropped up as an issue (*figure 5.9*):

> Let's see if there is anything else I would consider [removing]…people are interesting to get rid of as well. So we'll have a look. There is a person on the horizon there, we'll have to have a look at that. It looks really good, doesn't it? I'm sure that is me, sitting down over there in the corner. Let's clip that data, let's clip me…(Robert Shaw, Interview, 28/05/2019)

Comparing segmentation to photogrammetric cleaning illustrates how the inscription of performed material engagement—from acquisition to processing—can be expressed in both the structure and visual appearance of Cherish data. In the cleaning stages, the translation of spatial registers produced in the field and distributed through the sparse cloud are refined and calibrated. In this context, the points *least likely* to reflect an accurate translation of these spatialities are removed. As such, the integrity of the cloud is bound to the rigour with which specific aspects of a model's means of production is distributed across, and attached to, all the data which comprises it. Segmentation, by contrast, is when the visible evidence of a model's means of production is deliberately removed (*figures 5.10 & 5.11).*

Considered in concert, what these processes evidence is how the articulation of the knowledges inscribed within Cherish data indicates a transformation in the models ─ after Myers and Rheinberger ─ from "epistemic things" to "technical objects". That is, as the data

iteratively develops, it transitions from "a record of the intimate knowledge its modeler gained during its production" to something more accurately resembling a tool with prescribed purpose or functions (Rheinberger, 1998; Myers, 2015, pg. 78). In the overall project of parsing how the knowledges inscribed into by these models become constituted, then, the operations of cloud cleaning and segmentation are particularly useful. Object cohesion is predicated here on the translation and distribution of measurements and observations made in stages of acquisition, yet only to certain ends and within certain thresholds. As such, Karen Barad's notion of *agential realism* and DeLanda's notions of *territory* again find meaningful articulation here. On the one hand, the ontological correspondence agential realism draws between the performance of measurement or observation and the phenomena being measured or observed is evident; Cherish models are rendered through the reproduction and translation of distinct performed intra-actions and spatialities. On the other hand, the cohesion of these models is articulated through a series of inclusions and omissions mandated by territorialising factors such as protocol. Not all of the situation knowledges inscribed in the acquired datasets are translated as digital objects become coherent. Cherish models need to be both heavily edited and refined to realise their potential as tools of either analysis or demonstration. As a result, these digital heritage objects are perpetually defined both by their mutability and respective orientation within specific (but variable) parameters.

5.6 Step 7: building dense point clouds

Neither cleaning nor segmentation are final operations, however, and point clouds rendered during these stages are ultimately subjected to further processes of iterative development. The first of these is "dense" cloud construction. As alluded to above, the edited and cleaned sparse cloud is re-submitted to a similar process that produced it, but with more initial inputs and far richer results. Dense cloud construction also evidences just how time-consuming this process can be. Travelling to Dublin in May of 2019, Robert structured our daily

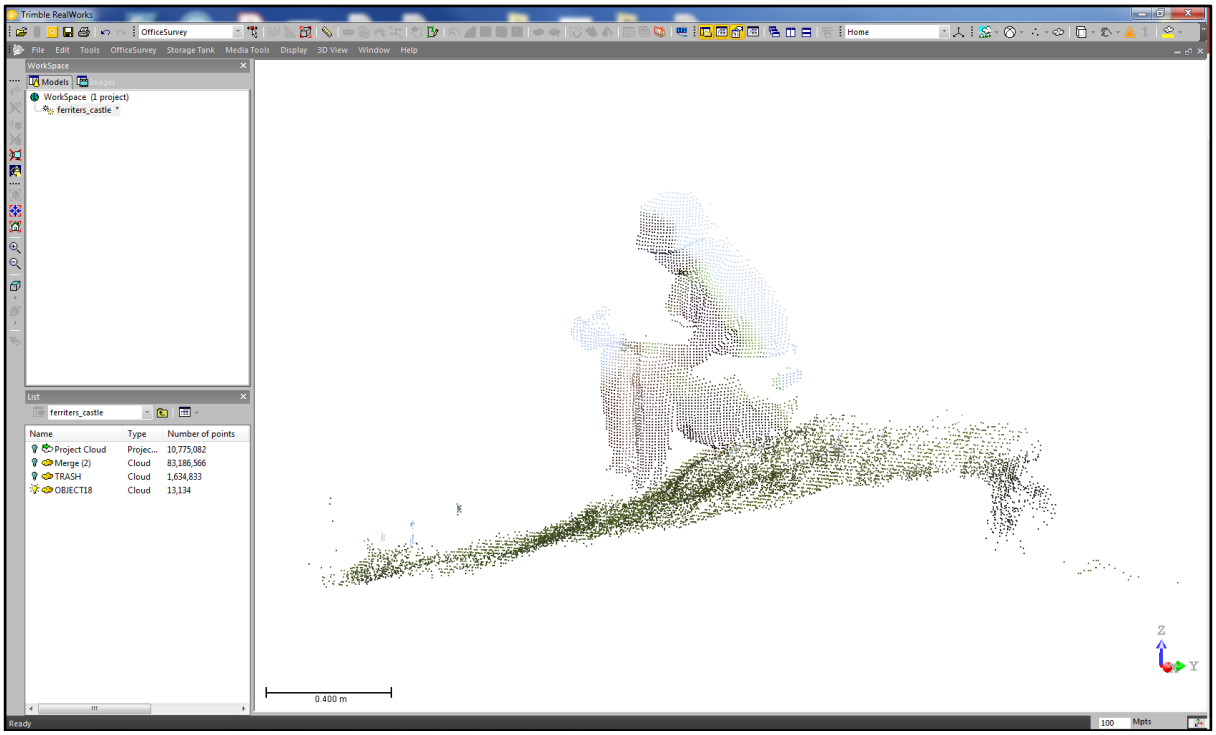
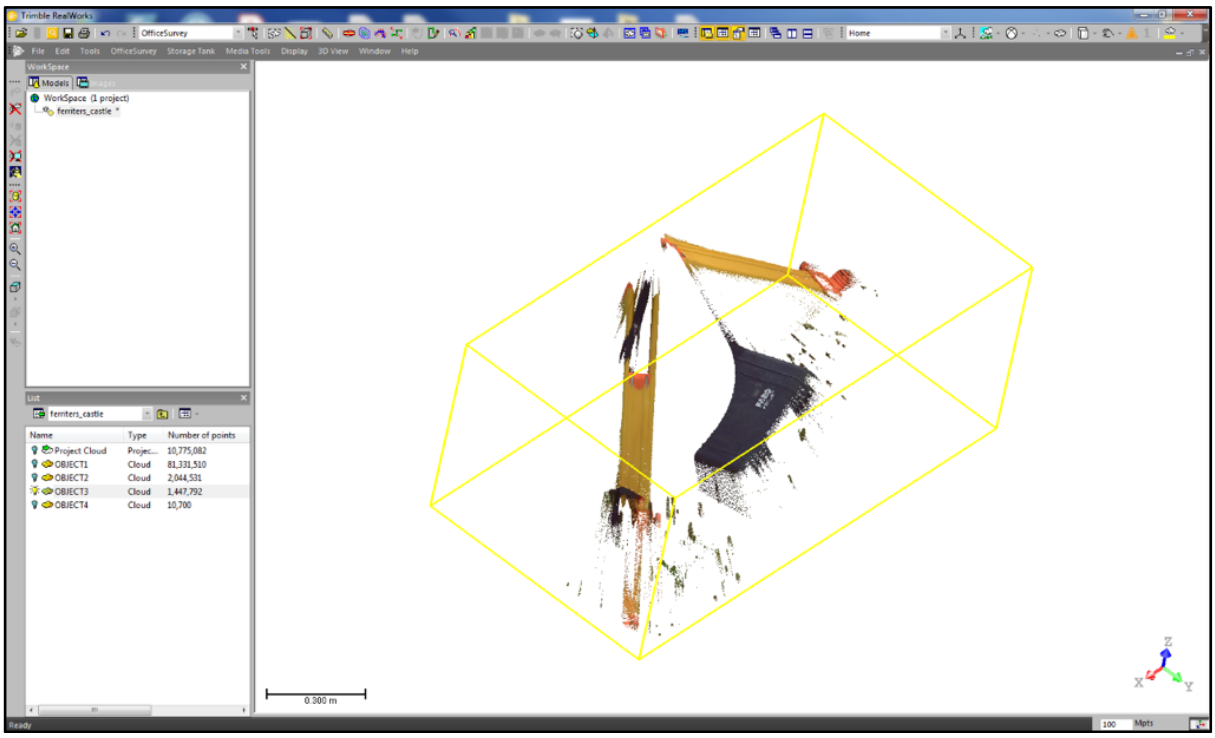


Figure 5.9. *A screen grab taken during the segmentation of scans produced at Ferriter's Castle. Here Robert highlighted and removed portions of the sparse cloud where he himself — as the practitioner performing the scan job — was visible in the scanned outputs. It is established practice at the Discovery Programme to remove any and all scanned evidence of the survey; tripods, equipment cases, and the people working to acquire such data. Source: model and screen grab by Robert Shaw.*



Figures 5.10. *Much like figure 5.9, here is an example of one of the images normally removed during the segmentation stages of a scan project; the tripod upon which the scanner was mounted. Given that scanners provide a near 360° overview of the areas they scan, they often return images of the tripods upon which they are placed.*

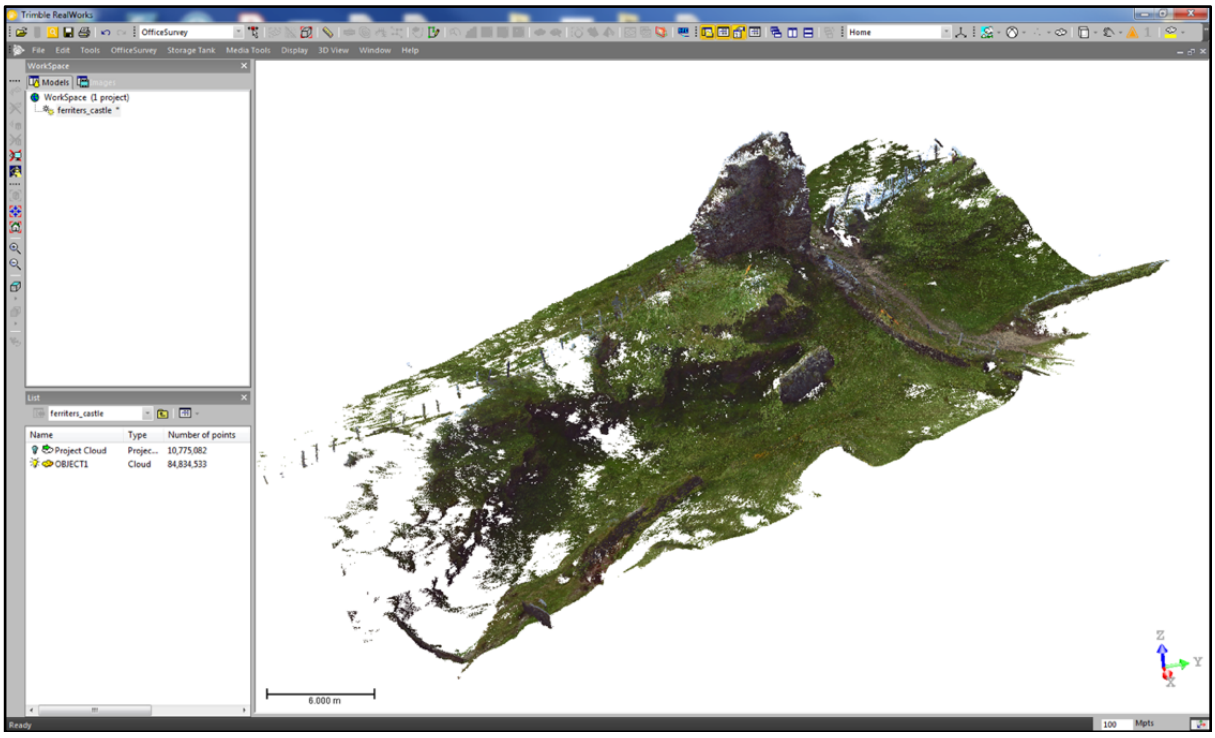


Figure 5.11. *An overview of the parent scan for Ferriter's Castle during segmentation. Robert would zoom in and, using the segmentation tool, highlight object's he opted to remove, cut them, and paste them into the parallel folder for extraneous scanned objects. Source: screen grabs and models by Robert Shaw.*

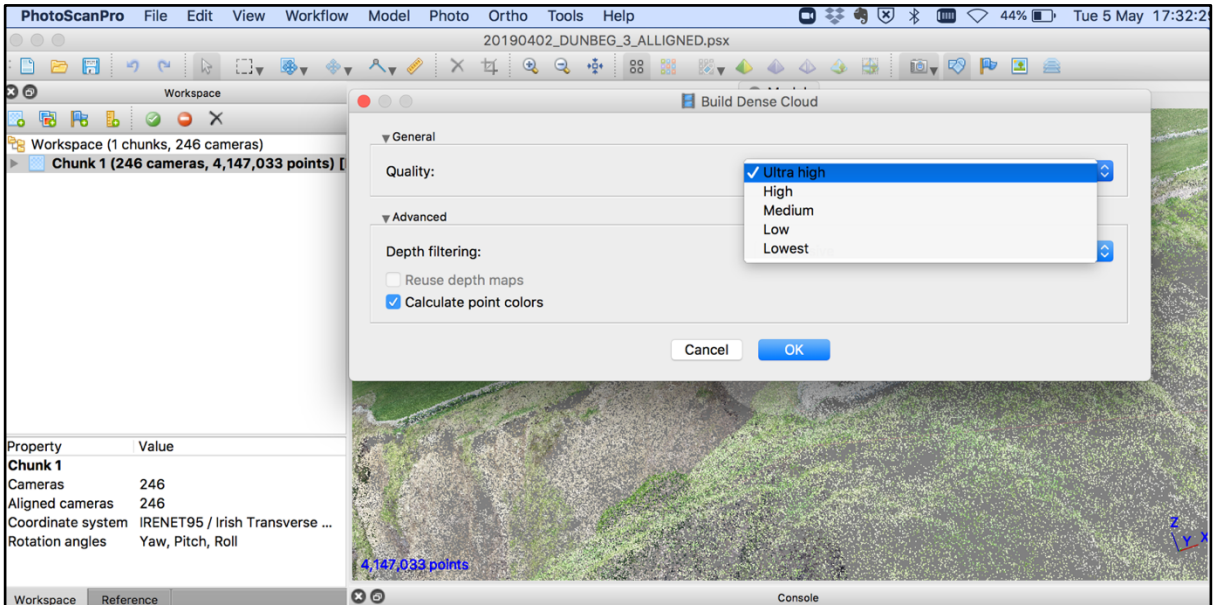
sessions around the data collected at both Dunbeg Fort and Dun an Oir. He had processed the data from Dunbeg before my arrival, saving his work as separate files after each iterative step in order to be able to provide an overview of the entire process without having to wait for each operation to complete. We simultaneously began working up the data from Dun an Oir (which he had yet to process), providing the opportunity to observe the unfolding of a similar project in real time.

Where our overview of the Dunbeg content was confined to a full working day, the Dun an Oir processing elapsed over a total of three. The building of dense clouds, in particular, being the most time-consuming of all operations observed during the visit. The reason for this, however, became immediately evident during the Dunbeg demonstration. Pulling up both the dialog box used to initiate the operation (*figures 5.12 & 5.13*) as well as the statistical analysis for the dense cloud he had already produced, Robert explained both the inherent variability at this stage as well as the massive multiplication of the original input:

> [Photoscan is] black-boxed, but ultimately with a huge number of variables. You know, you can really change the outcome. So, you just go to the next step, which is "build dense cloud". We tell it…we've got these various things—I think we've played around with "ultra-high" and I think it just crashes it. It just takes too long. So we've ended up going for the "high" option and the "aggressive filtering". I don't know about the "point colours", I assume that's ticked. So we just use that. But I know that takes forever, so here is one that I prepared earlier…It really doesn't look *that* much different…but the dense cloud has gone up to 100,000,000 points, from 2,000,000 points. And this tells you here— this is an interesting stat—that it took 10 hours and 41 minutes [to complete] (Robert Shaw, Interview, 27/05/2019).

To look at them casually, sparse and dense clouds do closely resemble one another. Advancing visualisation data from sparse to dense clouds, however, ultimately enables practitioners to render up datasets as cohesive geometric wholes and surfaces[67]. Yet by virtue of increasing the number of points by a factor of 50, the models at this stage exhibit a

[67] As will soon become evident in the subsection on terminal translations, the increase in cloud points corresponds to the number of polygons that will ultimately constitute such surfaces. The more points, the more polygons. The more polygons, the smoother the surface.



Figures 5.12. *A screen grab of the "Build Dense Cloud dialog box. Dense cloud construction is the most demanding, from a processing perspective, on the Discovery Programme's workstations. As such they rarely push the software to its utmost capacity.*

DUNBEG_2019_control_errors.PNG

Search

Markers	East err (m)	North err (m)	Alt. err (m)	Accuracy (m)
T1	-0.009913	0.004176	-0.041752	0.005000
T2	-0.017164	0.019538	-0.039927	0.005000
T3	0.005978	-0.002225	-0.010202	0.005000
T4	-0.007013	-0.010197	0.012853	0.005000
T5	0.004803	-0.004613	0.048519	0.005000
T6	0.005346	-0.018947	-0.002348	0.005000
T7	0.003374	0.033344	0.004867	0.005000
T8	-0.002789	-0.005304	-0.044871	0.005000
T9	-0.001597	-0.017976	0.040244	0.005000
T10	0.017910	0.020683	0.005944	0.005000
Total Error				
Control points	0.010238	0.013581	0.033564	
Check points	0.006788	0.022273	0.024307	

Figure 5.13. *A screen grab of one of the tables Photoscan will produce concerning the error distributed across the control targets used to geo-rectify the point clouds. In the image above the error returned is within and under the thresholds outlined in the Cherish manual for photogrammetry. Source: screen grabs by Robert Shaw*

tendency to crash both Photoscan as well as the internal graphics cards of Discovery's desktop computers. As a result, a conundrum presents itself at this stage. Models worked-up to this point are by far the most complex articulations of the data from which they are derived, yet they're too massive and unwieldy to be effectively used in any context of analysis or demonstration. Their value, then, is defined by their propensity to be re-structured and re-visualised towards different ends. While not explicitly a terminal output, dense clouds are produced in order to serve as dynamic templates for both current and future projects. Much like the duplicated cache of the images Daniel transferred to the project server, Cherish protocol calls for all dense clouds to likewise be archived for this reason. As such, while dense clouds serve as the primary basis for the derivation of many of Cherish visual outputs, such outputs are derived through processes of reduction and refinement. Often they reflect comparatively little of the complexity of the dense clouds from which they are produced.

5.7 Steps 8-9: processes beyond the manual

Within the current context of Cherish, dense clouds are used to generate visual products for either analysis or demonstration. Given the emphasis placed on the monitoring and analysis of land-loss at Cherish sites outlined in the original Charter (*appendix I),* dense clouds are often translated back into two-dimensional visual products. Primarily materialising as either DEMs (digital elevation models) or Ortho-mosaic imagery[68], such products are usually put to use in raster-based analysis[69] (commonly facilitated via ArcMap). Processing the data from a collection of digital photographs, to three-dimensional dense clouds, to 2D mapping products

[68] Ortho-mosaics are two-dimensional images produced from three-dimensional renderings. Because they're produced through photogrammetry, the objective is to have close to no radial distortion anywhere within the images, meaning geo-locative data can be populated across the entire image with remarkable accuracy. Often Ortho-mosaics are analysed using GIS softwares like ArcMap or QGIS.

[69] Data can be visualised within a GIS in one of two ways: as vectors or as rasters. Vectors are strictly point and line based, where rasters uses cell-based imagery to represent location and position within a geo-referenced workspace. Given that any of the two-dimensional outputs produced from photogrammetry are exported as image files (such as jpegs, tiffs, or pngs), any type of analysis ― be it with ortho-mosaics or DEMs ― is inherently raster-based.

enables Cherish practitioners to push their geomorphological analysis to new standards of accuracy. More precisely, it is the structural and geometric complexity of the dense clouds—compounded by the exhaustive distribution and translation of situating locative data—that enables Cherish practitioners to exponentially increase the value of their two-dimensional visual output.

In the context of illustrative and digital outreach products, however, dense point clouds are translated into rather different 3D forms. Confined by the limits of either processing power or the file size requirements of browser-based application programming interfaces (APIs), the 3D products Cherish derives from dense point clouds are drastically reduced in terms of both their structural complexity and overall file size. This is commonly facilitated by first "decimating" the dense point cloud and producing a polygon-based surface via a process of both wireframe meshing and re-topolisation[70]. Given what type of model is required and for what platform will host it, a re-topologised model is often derived from a dense point cloud composed of hundreds of millions of individually geo-rectified points and translated to a cohesive surface made up of a couple of thousand polygons. Speaking with Aaron Deevy, I was struck by his assertion that much of the model's data is eventually reduced by nearly 95%-99% of its original size:

> …it depends on the model, because you are going to have to bring everything down past a certain [point], down past 1%, or down below 1%. It is going to start with a lower poly count, but you don't want to go too low in the first place, because if you bring it down to, like, 100 polygons, you really aren't going to retain much of the shape anyway. So there is kind of threshold of how far we actually need to go down. Like 5000, I think, is about as far down as I would go for most models anyway because everything can load them (Aaron Deevy, Interview, 28/11/2018).

[70] Generally an indication of the number and shape of the polygons composing the mesh.

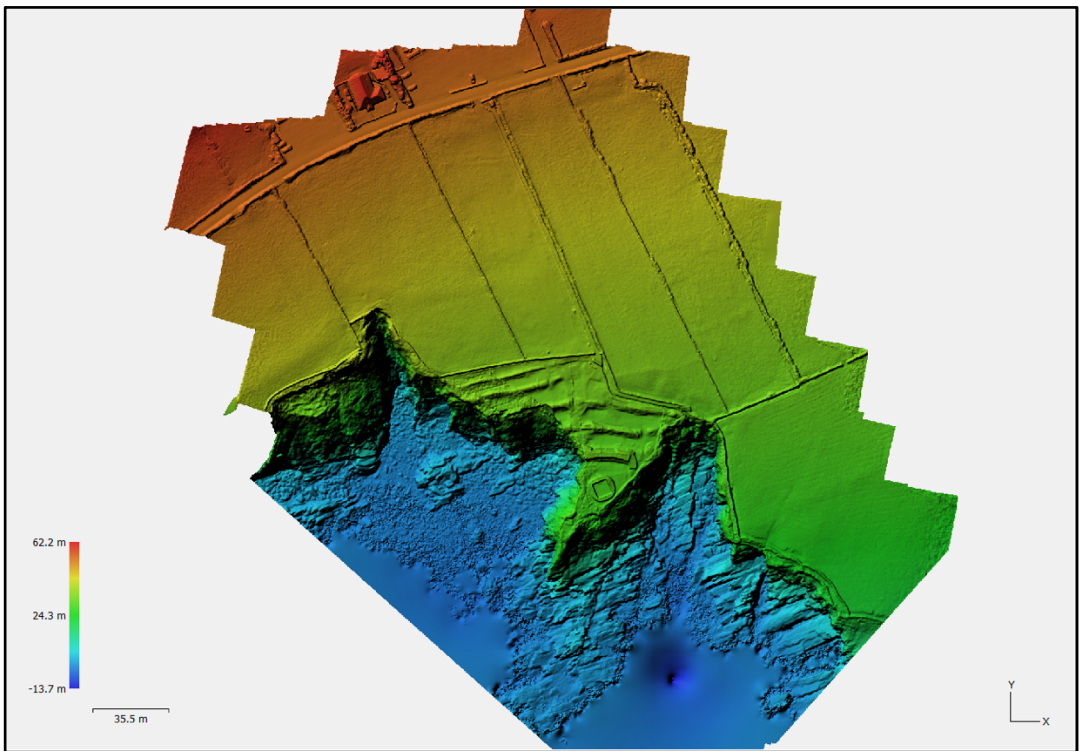
Aaron's finished products, however, *appear* remarkably detailed. Furthermore, because the majority of Aaron's products will ultimately be used as immersive illustration tools in conference or classroom settings, the reduction of their respective structural complexity is obscured—if not irrelevant—to those who might use them. When prompted to explain what of the 95%-99% of input data is removed, Aaron emphasised that their transformations were so profound it would be incorrect to even consider the finished product and its input as articulations of the same object. A claim which necessarily recentres any discussion of digital heritage objects around attendant parallel discussions about ontological multiplicity of digital objects more generally (as will be addressed in detail in the following chapter):

> [Its] the geometry and the shape. Its topology has changed entirely. I mean, you cannot say that the low poly model is the same object as the beginning model. There is a vast difference in the information that you are representing. Yes, it looks the same, but once it is put online you couldn't hold the two together, you couldn't do the same research on these two models. Even something as basic as measurement is going to be completely different. Like maybe by a couple of mm, but that makes a difference when you are talking about weathering or erosion (Aaron Deevy, Interview, 28/11/2018).

5.8 Conclusion

The Cherish Project storage databases at both the RCAHMW and the Discovery Programme already host scores of unique visualisations. Flagship[71] sites like Dunbeg Fort in Ireland, or Dinas Dinlle in Wales, have been already visualised as DEMs, ortho-mosiacs, and 3D models (*figures 5.14 & 5.15*). Comparing these visual products demonstrates the immense mutability of both the raw initial datasets acquired in the field and their potential to be differently articulated. This chapter has demonstrated how visualisations are achieved through the systematic integration of visual and coordinate-based datasets. It has also demonstrated how the various processes of integration are predicated on the fitting-together of the numerous

[71] Those which have been surveyed most regularly *and* have already been used as tools for outreach and analysis.



Figures 5.14. *A digital elevation model (DEM) of Dunbeg Fort, derived from a dense cloud of a survey conducted by the Discovery programme in 2018. The colour gradient visualised in the model indicates the respective elevation points for the surface of the site. Because this DEM is based on a dense cloud with a collective resolution accurate to a couple centimetres, models such as this can be contrasted with DEMs produced from previous or future surveys to assess where and how much of the site has eroded after storm events.*



Figure 5.15. *A finished 3D model of Dunbeg on Discovery's Sketchfab page. Models such as this one primarily serve as outreach tools and illustrative examples of the ongoing work within the Cherish Project. Source: DEM modelled by Robert Shaw, 3D model produced by Aaron Deevy.*

spatialities inscribed in the parent data during the preceding stages of acquisition. Therefore, processes of integration have been defined here as processes of *translation*, with the collective translation of numerous spatially inscribed datasets resolving in new articulations of visual and locative information. Like the datasets from which they have been derived, these new visual articulations are similarly defined by both assembled components necessary for their production and the extent to which these processes should be understood in terms of situation. The coherence of survey data as various kinds of digital objects not only emerges as a result of the intra-action of the components assembled at these stages, but are also, in part, defined by the circumstances and configuration of such intra-actions. Furthermore, both the situatedness of theses translations and the coherence of digital objects is determined by the negotiation of both professional decision-making as well as the agencies embedded within the softwares used throughout the described processes.

In the initial stages of *project set-up, the importation of data, the registration of image coordinates, and photo-alignment* ― for example ― practitioners exercise procedures of both data evaluation and system calibration in order to ensure that the integration of separate datasets happens smoothly. Particularly in the stages of photogrammetric "alignment", the combination of user input and software functionality produces conditions where both the calibrated systems of spatial reference and the gradual organisation of visual data develop in tandem. Part of what is further evidenced through this process is how the integration of spatial registers ― as well as the translation of two-dimensional visual data into 3D forms and surfaces ― is inherently co-constitutive of and coeval with the objects they eventually come to form. Crucially, *new* spatial registers are also produced as a result of their assemblage, registers defined by the situated configuration and co-functioning of software, expertise, and data in site-specific circumstances and arrangements. Following John Law, the chapter has also demonstrated how visualisation processes further spatialise data acquired

through survey, and how the production of these new spatialities are mutually generative of and with the cohesion of digital objects (Law, 2002).

In the *distribution of control*, a distinct series of locative measurements acquired in the field are imported and distributed through the gradually accruing sparse point clouds. Not only does this process point to how specific acquisition procedures are translated into new digital contexts, but further demonstrates how and where situated and performed activities come to shape the truth claims (namely, the "accuracy") attached to ─ and carried by ─ the resulting visual products. The *cleaning of clouds* and the processes of *segmentation* that follow, on the other hand, point towards instances where the rendered data are subjected to a series inclusions and omissions. As the projects first develop as *dense point clouds* and eventually into final products (the aforementioned DEMs, ortho-mosaics, and 3D models), the structural complexity of the data is first elaborated, then reduced, or dramatically reconfigured.

In short, this chapter has demonstrated that sites of visualisation and processing are produced through practices which translate, reduce, and rework the data acquired in the field. In following the development of Cherish data from the field to the office it has emphasised the inherent multi-sitedness of these visualisation practices, while simultaneously detailing how such practices are also defined by the *translation* of the situated spatial registers inscribed in Cherish data from one site of activity to the next. In so doing, it has also described the various ways in which these processes of translation take shape. While some spatial registers remain such that the visualisations can continue to be understood as being a 'circulating reference' to the processes of acquisition, others are defined by the new spatial registers produced through the very act of their translation. This chapter has used the official Cherish photogrammetry workflow manual as an organisational template, which has not only enabled us to trace the iterative development of Cherish data, but to do so in way that

spotlights it at key stages of cohesion: as a loose collection of .cvs files and photographs, as sparse and dense clouds composed of millions of points, as a wire mesh, or an ortho-mosaic. It has traced the translation of hundreds of files into a single PDFs, .obj files, or TIFF files. This chapter has deliberately focused on one of the primary research questions for this thesis overall; namely, how digital heritage data changes as it moves between stages of development. The following chapter continues to address the cohesion of digital objects, asking what they are and how/when they are formalised. Where this chapter, and the one before it, deliberately targeted the *production* of Cherish data, the next will specifically consider the ontologies of the digital objects once formalised as finished products.

Chapter 6: Digital Heritage Objects

6.1 Introduction

Thus far we have followed the production of Cherish data from its initial acquisition in the field to its subsequent translations during stages of visualisation and processing. The previous two chapters have traced how this data is produced, how it travels, how it changes, and — in many instances — how these different practices result in distinct outputs. Depending on the specific circumstances or practices, the nature of these outputs — and, by extension, how we should discuss or understand them — can vary drastically. During efforts of acquisition, for example, the procedures performed by Cherish practitioners result in two core dataset types: geo-spatial coordinate data and digital visual data (images and scan points, for example). These datasets primarily serve as the raw inputs used in the procedures described in Chapter 5, procedures which likewise produce new and varied outputs of their own (such as point clouds, wireframe meshes, digital elevation models, ortho-mosaics, etc.). Where the previous chapters have detailed the assembling and arrangement of the constituent parts and pieces that make the production of this data possible, this chapter explores how some of these outputs become produced as "finished" under situation-specific conditions. In particular, this chapter asks both how these particular outputs — through all their translations — come to be assembled as *digital heritage objects,* and what the consequences of these processes are. Understanding how digital data can become an 'object' is not straightforward. A digital object is not simply one of the 3D models loaded onto the Sketchfab platform, for example. Rather, this chapter argues that digital objects are defined by their mobility and ontological multiplicity.

Turning the discussion towards a more explicit consideration of digital objects, however, first requires a more pointed discussion about how this thesis conceptualises the data Cherish produces. Following Rob Kitchin, much of the data that emerges through the Cherish workflow can broadly be understood as:

> ...the raw material produced by abstracting the world into categories, measures and other representational forms—numbers, characters, symbols, images, sounds, electromagnetic waves, bits—that constitute the building blocks from which information and knowledge are created (Kitchin, 2014, pg. 1).

To go a little further, however, requires acknowledging the ontological multiplicity inherent embedded in this definition. Again, after Kitchin, the data outputs produced by Cherish can be understood or categorised with respect to how they are:

— ***qualitative*** **or** ***quantitative*** in nature: i.e., the difference between a list of GPS coordinates and a digital image. Or between something like a point cloud and the coordinate-based data inscribed within it.

— ***structured, unstructured,*** **or** ***semi-structured***: namely, a given data or dataset's propensity to be organised and/or searchable within the context of a relational database. As this chapter will further detail, all the data Cherish produces are sorted and organised within such databases.

— ***captured, derived,*** **or** ***exhaust***: Captured data refer to the primary outputs of measurement and observation, i.e. what Cherish practitioners call the data they "acquire" in the field. Derived data refer to the data which are " produced through additional processing or analysis of captured data", such as the point clouds, meshes, etc. detailed in Chapter 5. Exhaust data, finally, refer to data which is "inherently produced by a device or system, but are a by-product of the main function rather than the primary output" (Kitchen, 2014, pg. 6).

— ***indexical, attributive, or metadata****:* Indexical components of data are those which enable *non-indexical* data to be aggregated, disassembled, searched, and/or otherwise processed (Kitchin, 2014). Indexical data are a key component of whether or not a given dataset might be understood as *structured* or not, for example. Indexical data are defined by their

relationship to other data and larger datasets. Attribute data, by contrast, are "data that represent aspects of a phenomena, but are not indexical in nature", i.e., those which describe the location or appearance of specific aspects of a feature or landscape Cherish might target (Kitchin, 2014, pg. 8). Finally, metadata ("data about data") “help a user of a dataset to understand its composition and how it should be used and interpreted, and facilitates the conjoining of datasets, interoperability and discoverability, and to judge their provenance and lineage” (Kitchin, 2014, pg. 9).

Cherish data can possess many of these aspects at once, and they can likewise change and develop as they travel between sites and processes. Captured/'acquired' data, for example, is eventually processed into derived data (as detailed across chapters 4 and 5). Similarly, the images produced through drone-based photography — despite being primarily defined by the attributes of the features they capture — become indexical by virtue of how they are tagged or organised when they are entered into Cherish databases. Furthermore, the degree to which these data can be understood as "the building blocks from which information and knowledge are created" is densely bound up in how data is processed and synthesised into *new* assemblages in order to become useful or take on distinct applications.

It is this iterative combining of data that results in the production of digital objects; captured or "raw" inputs are ultimately translated into what Kitchin would describe as 'secondary' and/or 'tertiary' data (outputs which take on prescribed uses and functions both different from their primary inputs and accessible to parties beside those who produced them) (Kitchin, 2014). Furthermore, Kitchin consistently conceptualises data in terms of historical and geographical contingency, contending not only that how "data are processed and analysed mutates over time", but that, as "epistemological units" which enable "epistemological work", analysis and processing are fundamentally shaped by changes in administration, technology, and methodological innovation (Kitchin, 2014, pp. 17-19). As

such, both data *and* the digital objects they come to comprise must be considered within the context of the coordination of external components that define them in site-specific and situated contexts.

Media theorist Yuk Hui contends that the predominant discourse on digital objects is too often driven by the problematic impulse or tendency to commute our collective understandings of physical things and technical objects into our consideration of the digital. The issue, then, is that digital objects (or data objects, as he sometimes refers to them) are not only crucially related to the relational assemblages that facilitate their use and application, but that they exist in two distinct ways: both in the front-end of interfaces and in the back-end of processors and computational systems (Hui, 2016). A digital object — such as a digital elevation model of an iron age promontory fort, for example — will appear to a user in a fashion that could be described as familiar or traditional; as a visible and tangible tool with prescribed uses and functions[72]. Yet the same digital elevation model is also forensically reducible to granularities which often define the computational processes that enable such models to be interfaced in prescribed or expected ways:

> True, these objects appear to human users as colourful and visible beings, yet at the level of programming, they are text files; further down they are binary codes, and finally, at the level of circuit boards, they are nothing but signals generated by voltage values and the operations of logic gates (Hui, 2016, pp. 26-27).

For example, an individual digital image used for photogrammetric purposes — once subsumed into either a storage database or a larger set of images and coordinates composing a 3D model — might be viewed as both a discrete object in and of itself, and as a constituent piece of the models it can help to animate. In one respect, this can be taken to mean that digital objects, much like the data from which they are derived, are similarly ontologically

[72] A user can grab it with a cursor, zoom in and out to explore new perspectives, and use application tools to perform measurements, etc.

multiple. This is further compounded by the fact data and the objects they respectively compose drastically change as they travel between different databases, interfaces, and platforms (Steyerl, 2012; Kitchen, 2014; Wiltse and Redström, 2016). In short, the ontological status of a digital object is bound up both in relation to its constituent parts, as well as its capacity to be alternately interfaced.

There is a temptation here to frame our understandings of digital objects merely as *data assemblages*, but this would be an over-simplification. Not only is the cohesion and formalisation of data-as-objects facilitated by components that are *not* data — softwares, platforms, the enacted expertise of practitioners doing analysis, etc. — but *how* a digital object can be *used* also depends on specific contexts of application (i.e., the components, interfaces, and platforms necessary to apply a digital heritage object in a given task). To these ends, the distinction between data and digital objects this chapter will trace is primarily derived from the relationship Natasha Myers describes between *epistemic things* and *technical objects*. To reiterate and paraphrase Myers, an "epistemic thing" is defined as a record of the knowledges gained by a practitioner during that "thing's" production (Myers, 2015). As an epistemic thing, something like one of the Cherish project's many sparse point clouds, for example, would be understood to contain both key data produced through measurements and observations enacted by practitioners in the field, as well as the inscribed metadata detailing such data's "provenance and lineage" (Kitchin, 2014). Myers defines "technical objects", on the other hand, as objects that were once epistemic things but, by virtue of their formalisation and refinement, can now be used to determine *other* epistemic things (Myers, 2015). To these ends, something like the raster-based DEMs Cherish practitioners use to conduct morphological analysis on eroding hillforts — which would be derived from the sparse point clouds mentioned above — cease functioning as epistemic things because they can be applied in new knowledge-producing practices (Rheinberger,

1998). This chapter will describe the conditions of these transitions, asking how exactly the technical/digital objects Cherish produces resolve in such a way as to no longer function 'epistemic things', and why. Furthermore, it will address the fact that these transitions are rarely linear processes. On the contrary, the cohesion of digital objects this chapter describes is often defined and complicated by the fact that their coherence is predicated on their movement to and from the Cherish database as well as across numerous platforms, softwares, and interfaces. As such, the understanding of digital heritage objects it produces is one defined by conditions of mutability, mobility, and ontological multiplicity.

The first section of this chapter concerns the databases both the Discovery Programme and the RCAHMW use to store and organise their outputs. While not an archive in the traditional sense of the term, both the Discovery Programme and the RCAHMW host their own databases on dedicated servers for storing the data produced through their surveys. These servers are organised in order to categorically sort individual datasets according to site location, methodologies, and data/file types (such as .jpeg files.obj files, Photoscan project files, .csv tables, and more). The databases themselves function not only as repositories, but as formalising structures through which the cohesion of digital objects at later stages is initially facilitated. As a result, this chapter considers these databases beyond their capacity for storage, addressing the distinct ways in which their inherent structuring serves to platform data between stages of iterative development and facilitate its movement between secondary softwares and interfaces (as it develops from captured to derived data, for example). Given how many of Cherish's prescribed methodologies resolve in similar data types (digital images in the case of aerial photography and UAV survey, for example), it is often *how* these initial inputs are organised or stored that determines how they will be used and visualised.

The second section addresses how the agencies of the softwares and platforms used to visualise and circulate Cherish data organise and process data in a manner that further

facilitates their transition from data to digital heritage objects. These agencies are described here in several ways. The first concerns the configuration of the components assembled in order to make the production of digital objects possible. In so doing, it further addresses the consequences of these configurations; namely, the degree to which the production of *derived* data necessitates skilfully implemented reductions and elaborations of *captured* inputs in order to produce specific types of objects. It also details how the context-specific arrangement of processing softwares and platforms are most often selected and used based on the processing limitations of either the softwares themselves or the interfaces ultimately used to circulate the resulting outputs. Finally, this section will also address how the prescribed uses or planned applications of digital heritage objects dictate which softwares/platforms can be used, how protocol is followed, and what type of objects ultimately result and when.

Given how both Chapters 4 and 5 have described how *situation* becomes inscribed in Cherish outputs at different stages, the final section of this chapter addresses how metadata and these situated inscriptions evolve and change as their outputs transition from epistemic things to technical objects. The ontological multiplicity of *data* is firmly associated with context specific configurations of who produces it, who analyses it, and who draws conclusions from it (Kitchin, 2014). The question, however, becomes whether it is possible to conceptualise the ontological multiplicity of *digital objects* through similar means. In tracing the iterative development of metadata as Cherish datasets travel and cohere, this portion of the chapter explores the extent to which the refinement and integration of datasets as digital objects is predicated on whether such objects remain "intimate records of the knowledges gained" during their respective acquisition and processing (Myers, 2015, pg. 78).

6.2 The Cherish Database

For both the Discovery Programme and the RCAHMW, storage databases sit at the centre of almost all of their activity. As practitioners return from the field, they immediately transfer their acquired data there for storage. As practitioners begin to visualise acquired datasets as point clouds, meshes, DEMs, or ortho-mosaics, these parent databases serve as both the source from which inputs for processing are retrieved *and* where subsequent stages of a given project are saved as it develops. To no small extent, *what* digital objects can be produced from Cherish data is substantially determined by how and where datasets are situated within their parent databases. These databases associate disparate sets of data in ways that anticipate their potential to be formalised and visualised together. Furthermore, by virtue of their deliberate structuring and organisation, they are also designed to anticipate both the ongoing proliferation of data at sites of repeated survey *and* accommodate varied visualisation methodologies now and in the future. To these ends, the structuring of Cherish databases can be understood in terms of what Jussi Parikka has described as the "intellectual scaffolding" inherent to data systems and structures. To consider this scaffolding, Parikka contends, "leads us into questions where media becomes less about devices per se, and more about where they connect" (Parikka, 2017, pg. 5). Critically, however, Parikka further contends that acknowledging the agency of such organisational structures further demands due consideration of the contextual situatedness that ultimately defines these conditions of data-relationality:

> Data emerges as relations which internally link data points as patterns that become meaningful, not necessarily in the humanistic sense of the term, but when handled as an input for governance, marketing and management. But this mobilization of data and its relational existence in institutions, uses, and discourses must be approached in situated and context-specific ways as it extends outside a focus merely on data sets and data structures (Parikka, 2017, pg. 6).

Much of what the previous empirical chapters have established is the inherently situated nature of both the acquisition and processing of Cherish data. In using the Cherish database

as a means to begin considering where, when, and how such data begins to cohere as digital objects, however, the Cherish database is revealed as a context or platform of both coherence *and* dis/assembly. As such, the contexts or situations that describe or define Cherish's storage server — in Parikka's terms — are not static conditions but are fluid and responsive to both how the data is inputted *and* how its ultimately used.

I began discussing data storage early and often during my trips to Ireland and Wales. My entrance interview with Toby Driver, for example, was largely structured around his desk as he transferred recently acquired datasets to the Cherish database. Toby has worked as an aerial photographer with Royal Commission on Ancient and Historic Monuments of Wales since the 1990s. His book, *Pembrokeshire: Historic Landscapes from the Air* (2007), is widely read among both professional archaeologists and hobbyists interested in the coastal heritage of Wales[73]. He is also one of the principal organisers — along with Anthony Corns and Louise Barker — of the Cherish Project and helped to co-author its original application and funding charter. Unlike Robert Shaw or Daniel Hunt, however, Toby is relatively new to field methods such as UAV survey and laser scanning[74]. His participation in the project largely concerns the aerial reconnaissance, prospection, and identification of Cherish sites. To situate Toby and his work within the holistic methodological of overview of Cherish means not only thinking about the relationship between the different methods, but between the data he is directly responsible for producing and the data produced from the other methods as well. From a methodological standpoint, the difference between Toby's aerial overviews and more finely grained outputs such as the digital images produced for photogrammetry is how they function to produce different kinds digital objects. Where the

[73] On a field trip that took me to an excavation at Dinas Dinelle near Caernarfon, a student volunteer from Bangor University was so excited to meet Toby that he brought a copy of his book with him for an autograph on the second day of the dig.
[74] In fact, the survey I witnessed being undertaken at Nab Head (see chapter on '*acquisition*') was Toby's first time conducting drone survey as a newly licensed operator.

individual images produced through UAV survey, for example, ultimately function to be aggregated and processed in caches of hundreds of photos, Toby's outputs often serve as stand-alone units (*figure 6.1*). Beyond being both digital images and sharing file types (.jpeg, .TIF, etc.), the way in which such datasets might best be considered as being either comparable or distinct from one another is by attending to where and how they are placed within the project databases.

On my first trip to Aberystwyth in March of 2019, my initial conversations with Toby took place at his workstation, where he could provide examples of the outputs unique to his practice. At the time he was in the process of transferring a cache of photos to the commission's server which he had taken on a recent trip to "Ireland's Eye" and similar islands in and around Dublin Harbour. Combing through these images I found myself contrasting them with the drone-generated photographs Daniel had shown me while reviewing models-in-progress from sites like Castell Bach and Dinas Dinlle (*figures 6.2 and 6.3*). The differences between the two sets of images were subtle, distinguished only by the perceptible but vague presence of an editorial photographic eye somewhere behind Toby's lens[75]. To the untrained observer, however, they would appear remarkably similar; oblique overviews of structures and landforms taken from similar distances[76]. The differences between them only became truly pronounced as I became familiarised with how either Toby or Daniel (or Robert) worked with their large visual datasets in management and storage contexts. Simply put, it was the act of storing and organising such datasets that marked them as being fundamentally different from one another. Which is to further say that it was their respective categorisation as principal data types — for either prospection or photogrammetry, say — that determined the types of digital objects they either already were, or could eventually

[75] See chapter on "acquisition" for discussions on the projected nature of vision afforded by drone photography.
[76] In my entrance interviews with Anthony Corns, for example, he made specific mention of a side project he was undertaking to generate a 3D model using a set of aerial images taken in the 1970s.

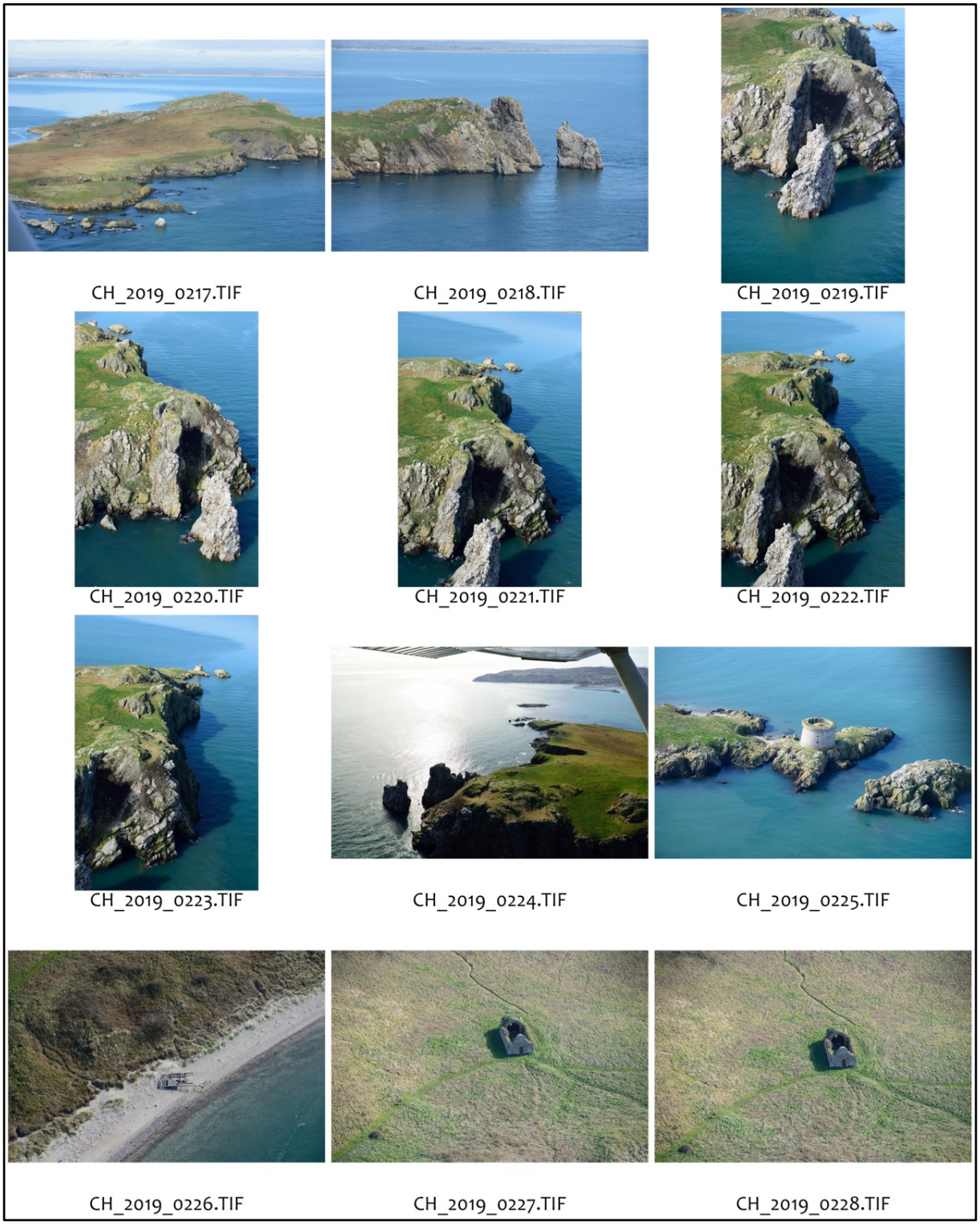


Figure 6.1. *One of many contact sheets Toby shared with me of the digital aerial images he had taken during a reconnaissance flight around Dublin Harbour and Ireland's Eye in the early spring of 2019. Sequential images of the same sites and features (such as images CH_2019_0219 through CH_2019_0223 above) appear very similar to those acquired via oblique photography flights during UAV survey. Were Toby to have taken similar images completely circumscribing this headland he could have easily produced a photogrammetric model from this particular flight. Source: photographs by Toby Driver.*





Figures 6.2 & 6.3. *Compared with the images Toby produces on his aerial missions, drone images, such as these produced by Daniel Hunt at Dinas Dinlle in 2018, appear remarkably similar. The detail and perspective afforded by the drone would be sufficient to conduct prospection on this site, for example. What marks them as being fundamentally different datasets, however, is their relationship to the other images grouped within their parent datasets. Images such as these, for example, are just two of hundreds from which photogrammetric models were later derived. Source: photos by Daniel Hunt.*

become. In many respects, Toby's outputs could already serve as technical objects; outside of some cosmetic editing, his aerial images required little processing in order to assist practitioners in identifying new survey locations. In other instances, Cherish practitioners treat photographs *as* data with various use potentials (Hoelzl, 2015; Mackenzie and Munster, 2019). Daniel and Robert's outputs, by contrast, would be treated more formally as captured data from which further data could be derived — derived data which could in turn be used to render DEMs, ortho-mosaics, or 3D models. Part of what this points to is how a digital image's status as a digital object is not only determined by how practitioners intend to *use* it, but — by extension — how it is relationally associated (or not) with other datasets, softwares, and interfaces ahead of its processing and/or interfacing. Furthermore, the fact that Toby's outputs could fulfil their function as prospection tools without undergoing extensive further processing evidences that digital objects cohere within the Cherish workflow at different stages.

It wasn't until months after my initial conversations with Toby that I was given a thorough introduction to the structuring and design of the Commission's database. Having returned to Aberystwyth from Pembrokeshire (where we had performed both UAV survey at Nab Head and plane-table drawing at Carfai), Daniel walked me through the initial protocol he, or any Cherish investigator from the Commission, would use for storing and cataloguing field data within the database ahead of its processing[77]. Here he used the transferring of the data from Nab Head as a means to introduce me to the file-structuring format he had devised for the project overall. As a file directory, the Commission's Cherish database is first organised by regional area (enumerated 1-13 for the sites in the Welsh remit) with individual field-sites further nested within each of these 13 parent folders. Working with the data

[77] This database, it should be noted, is one of Daniel's own design (although the file structure used in Ireland is remarkably similar).

acquired at Nab Head, Daniel began by first opening the parent folder for "Survey". The survey folder then opened into further nodal sub-groups (*figures 6.5 and 6.6*). Within each site's survey folder (such as the file for Nab Head) were further folders specific to what type of survey had been undertaken; UAV, laser scanning, geo-physical survey, etc. Inside the UAV survey folder were three specific sub-groups; "raw photos", "working photos", and project folders (which Daniel labels "archive files"). I was struck by the fact that the images populating both the "raw" and "working" photo folders were identical. At least at first. Transferring the data we had collected in Pembrokeshire, Daniel would explain that the images stored as "raw" photos were to remain untouched in perpetuity, where the duplicates stored as "working photos" would be used as the baseline data from which subsequent visual products could be derived. Furthermore, once visualisation projects have begun (such as photogrammetry, for example), the iterative stages of such work (sparse point clouds, dense point clouds, optimised dense point clouds, etc.) would be saved within the databases folders for "working projects". Daniel also was quick to point out that many of the folders — at least at this stage — were empty, meaning that he had included field-sites yet to be digitised or surveyed into the over-arching organisational structure he had devised.

The relationship between Cherish data and the Cherish databases, in many ways, is similar to the correspondences media scholars have drawn between images, archives, and meaning making (Rose, 2000; Sekula, 1986). In transferring survey data to the database these primary or captured outputs are not only organised and sorted but become referentially tagged with meaning. Where within the database they are sorted, for example, indicates not only how they are most likely to continue developing as digital objects, but how they will most likely be viewed and applied by users at later stages. As such, despite the fact that Toby's images from Dublin Harbour and Daniel's from Pembrokeshire were technically remarkably similar, their respective potentials to co-constitute digital objects were

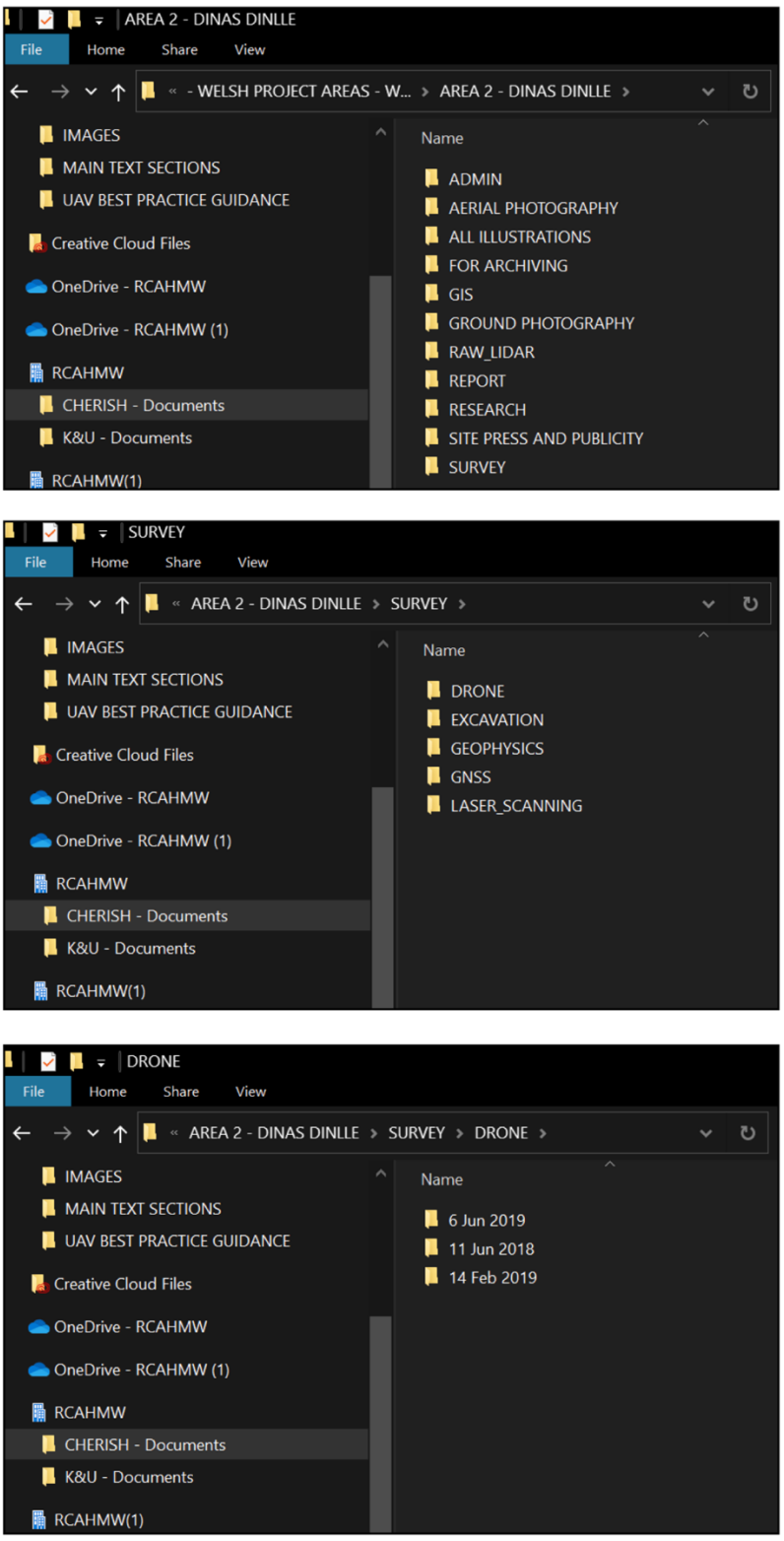


Figure 6.5. *Screen grabs of the nested file structure of the Cherish database at the RCAHMW. The top cell details all the parent folders clustered for the site of Dinas Dinlle. These files run the gamut from cartographic materials (sorted in the GIS folder) to all the various surveys either already conducted or planned for the future. The second cell is the survey folder for Dinas Dinlle where separate files for surveys either already conducted or planned are organised. The bottom cell details the contents of the Drone Survey folder for Dinas Dinlle. Source: screen grabs by Daniel Hunt.*

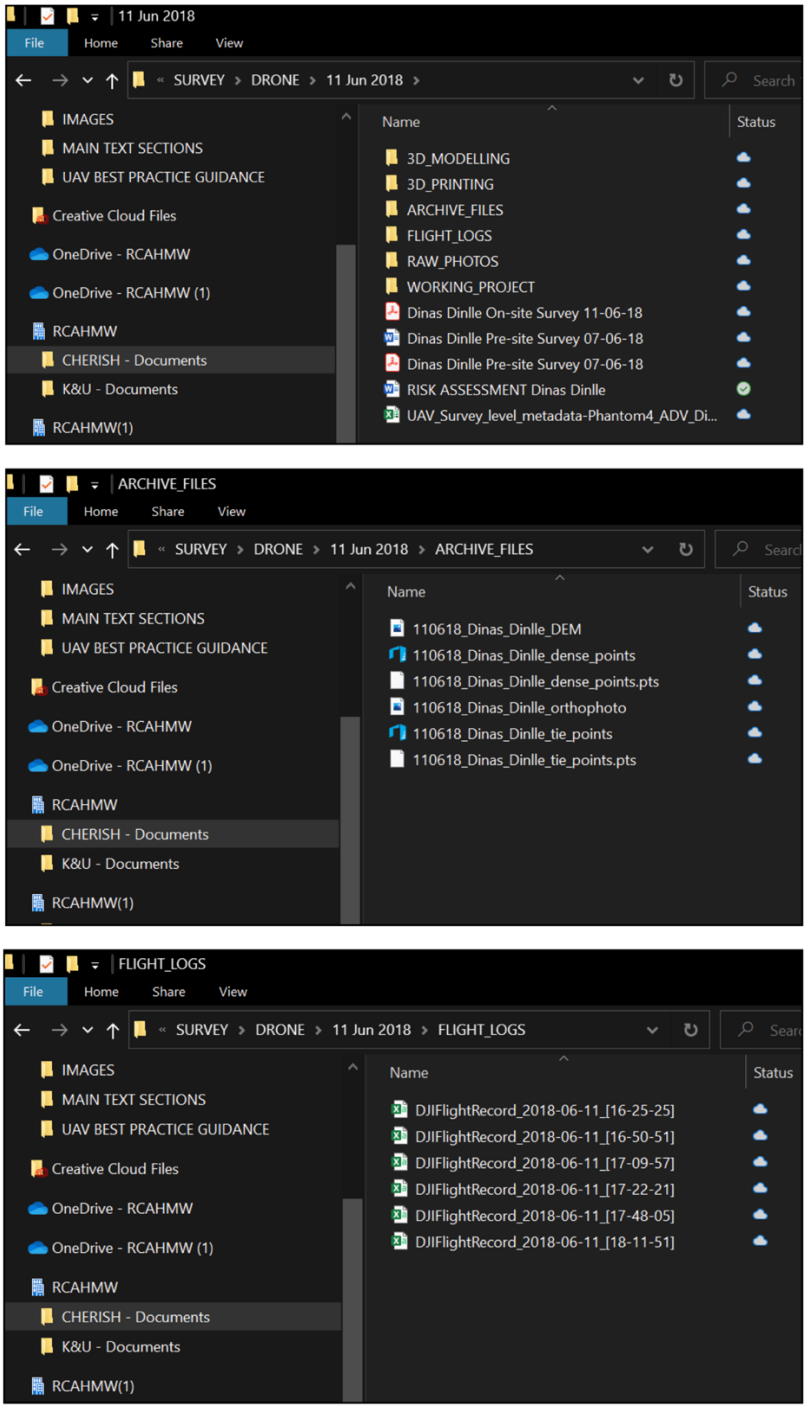


Figure 6.6. *As above, the cells in this figure further detail the files within the RCAHMW's database entry for Dinas Dinlle. The top cell details the contents of the drone survey conducted at Dinas on 11 June 2018. Here you can see the respective acquired datasets sorted as Raw Photos and Working Photos, for example. The second cell details the iterative stages of models made from this data which, in the case of this survey, have already been visualised as sparse clouds, dense clouds, ortho-mosaics, and digital elevation models. The final cell contains flight logs for this survey: essentially a detailed metadata overview of the survey. Source: screen grabs by Daniel Hunt.*

predetermined by where they had been initially stored. This is not to say, however, that the database definitively formalises data as objects, only that it can anticipate further formalisation at later stages and facilitate this formalisation by foregrounding meaningful associations between separate datasets within the context of a given site or survey. There is a way in which much of the "acquired"/captured data — even before its transferred to the database — could itself be individually defined as digital objects. This is most evident when considering an output like Toby's aerial overviews. Within Hui's terms, any digital image — once visualised through a viewing software and corresponding interface — enters an assemblage of external components constituting its ontology as a digital object. The same could be said for scan points, such as those generated by laser scanners or derived from images in photogrammetry. Each individual point within a cloud is not only tagged with spatial coordinates, but attributes pertaining to normal vectors, elevation accuracy, or colour (Otepka et al., 2013, Poux et al., 2016). Like digital images, these points become objects when they enter into relational configurations with other data and devices in contexts of processing or analysis. The takeaway, then, is not only that the cohesion of digital objects can occur throughout the entire Cherish workflow, but that derivation of *digital objects* with prescribed uses outside of survey and documentation is often predicated on the translation of digital objects into new relational configurations with other data *and* digital objects. Two key points follow. On the one hand, that data and the objects they compose can be defined differently depending on their relational configurations to other data/objects. On the other, that a database like Cherish's is more than a mere repository, but an infrastructure which platforms and anticipates these relational configurations.

The Cherish databases have also been structured in such a way to anticipate deposits of data far exceeding that which has already been generated. In many respects, the primary deliverable of the Cherish Project is the proliferation of a data baseline from which distinct

visual products might be derived both now *and* in the future. As such, the project is actively anticipating both the influx of new data and their potential to be formalised as objects in two distinct contexts. On the one hand there is the matter of storage space. On the other is how this data will remain platformed and organised in ways that will structure and dictate the data's use and application.

At the outset of the project the RCAHMW allocated only 1TB of space on its server exclusively for Cherish. Just months later Daniel, Louise, and Toby were already lobbying for more. Part of this is because both the Discovery Programme and RCAHMW are consistently updating their methodologies and approaches. In another sense, too, their capacities for "acquiring" and processing new data are also consistently expanding. The reality of constructing a repository to host their work, however, has occasionally bumped against administrative roadblocks:

> There is a tension between having working data that you need to have access to, and then you actually put it in a box and archive it through. Technically everything — well not technically — *everything* is retrievable through the archive. That's part of the point of Cherish; to have a recoverable data legacy. But the [people managing the] archive often do not want everything that you've got (Toby Driver, Interview, March 27, 2019)

This tension is indicative of another situational context defining the Cherish database. As a consequence, the "data legacy" associated with the database is necessarily also defined in terms of situation. What's retrievable, what can be formalised as an object, and how, is contingent not only upon the organisation or "intellectual scaffolding" of the database, but on its capacity to fluctuate and evolve in step with the project overall. Yet despite the fact that both Cherish teams have been able to secure enough for the project's database to grow, the scaffolding inherent to databases that will house these future additions will continue to influence the formalisation of this data in predictable ways. In order to take our understanding of Cherish's digital objects further, however, it now becomes necessary to

consider the organisational elements *outside* the database which are also generative of digital objects as data transitions from being stored and retrieved.

6.3 Software, Platforms, and Applications

As Cherish practitioners develop specific visual outputs (3D models, DEMs, etc.), they transfer data out of the database and through to the suites of software best suited for their specific goals. The data they transport from the database could either be the captured data produced in the field, or derived data which have already undergone different levels of processing (such as the dense point clouds detailed in Chapter 5.). Often the final outputs which result from these stages of translation are easily identifiable as objects with evident "front-end" articulations; they can be navigated and interfaced, they can assist in the performance of analysis and illustration. Following this data out of the database — where it is organised and stored on the basis for its *potential* to visualised in specific ways — their eventual coherence as identifiable objects is further predicated on the assemblage of softwares and components into which they are next inserted. Simply put, to become formalised as a digital heritage object outside of the database, this data must enter into new assemblages composed of softwares, platforms, interfaces, and users. As such, the resulting digital objects are crucially shaped by both the limitations and affordances of these assembled softwares and platforms used to render them, as well as the projected uses or anticipated applications for which they are produced. These two factors are densely interrelated, meaning softwares or platforms are deliberately assembled because they're both capable of working with data inputs in specific ways and of meeting specific demands for certain types of objects. The relationship between visualisation/modelling softwares and anticipated uses/applications of their outputs, however, is not a static one. Not only are the processing capacities of the individual softwares consistently changing — enabling the production of

increasingly dynamic visualisations — but as these outputs improve, their potential for application in analysis or illustration also changes.

As a result, despite the fact that the databases housing Cherish data have been structured in such a way as to anticipate the production of specific types of digital objects, the actual production of these objects is more fluid. Methods of visualisation and rendering consistently respond and adapt to what the assembled softwares, platforms, and interfaces can and cannot do with the data. As a consequence, the range of digital heritage objects the Cherish project is capable of producing is likewise always changing and adapting. The relationship, then, between the input datasets being modelled, the softwares used to render them, and the platforms used to showcase or interface such products is one defined by fluid and situated circumstances that ultimately define Cherish's digital heritage objects.

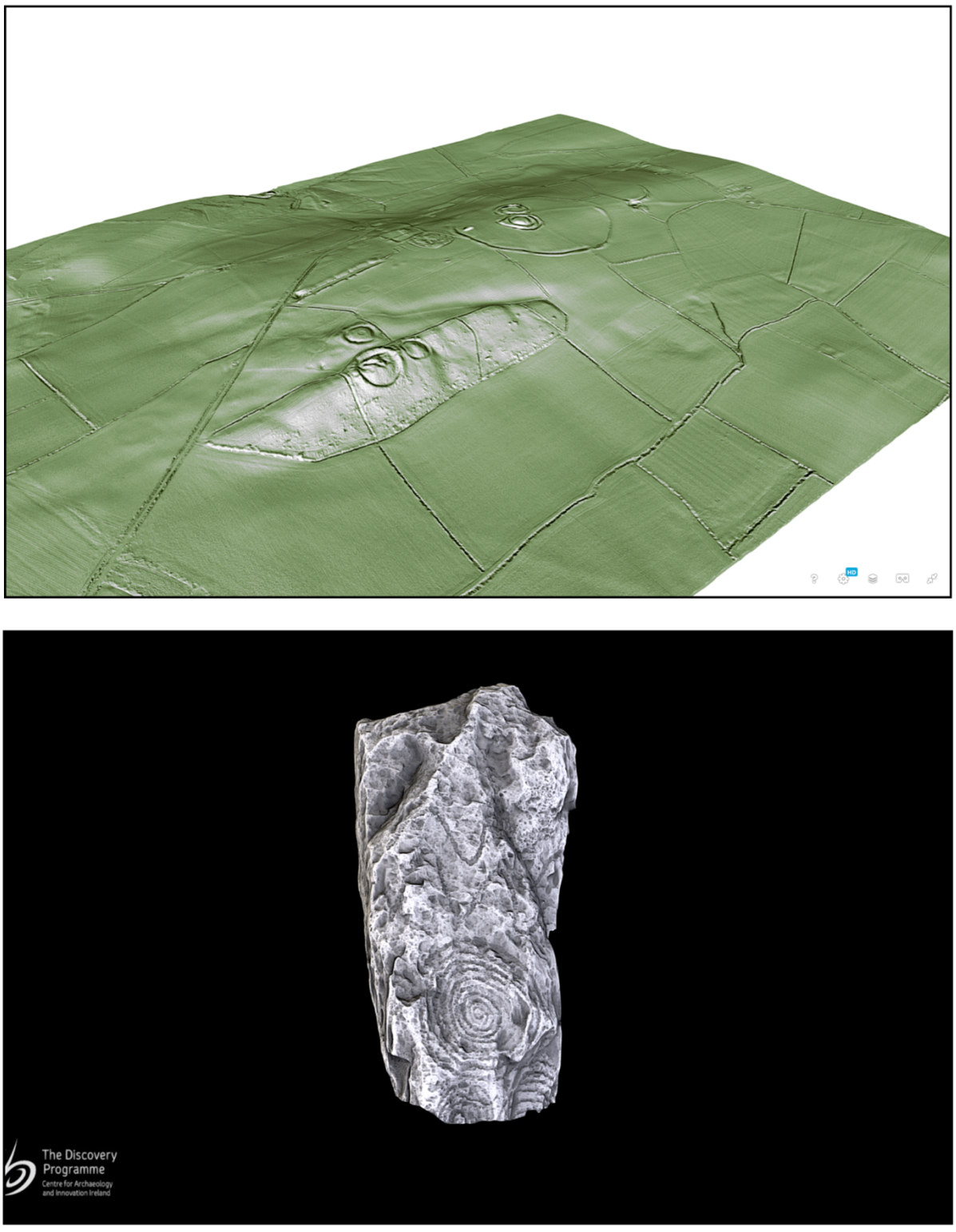
Early in my field work I conducted an extended interview at the desk of Aaron Deevy, the principal 3D modeller then employed at the Discovery Programme. Sharing an office with both Anthony and Robert, Aaron was primarily responsible for rendering dense clouds and wireframe meshes Robert had produced into accessible models for public consumption. Our conversation rapidly moved between the two large monitors on his desk, where open tabs of complementary softwares cascaded on top of each other, occasionally resulting in the inevitable hiccups of temporarily frozen screens and idly spinning pinwheels. The majority of Aaron's demonstrations concerned the various avenues through which laser-scanned or photogrammetric datasets might resolve as 3D models: an animated rendering of the Neolithic passage grave at Knowth, for example, or a selection of modelled landscapes from around Ireland that Discovery had modelled for its contribution to their "3D Icons

Project"[78] in 2015 (*figures 6.7 and 6.8*). Given my focus on the Cherish project, Aaron happily demonstrated some of the iterative models he had already made of rapidly eroding sites targeted by Cherish. As the most consistently surveyed site within Discovery's remit, Aaron's models of Dunbeg Fort proved particularly instructive here. Having seen data from Dunbeg at various stages of its iterative development, these models demonstrated how these public facing outputs compared to the captured and derived iterations of the data on which they were based.

The majority of Aaron's outputs — as well as the majority of the visual products the project has already made available to the public — function to *illustrate* the effects of climate change on coastal heritage. Despite the fact that the entirety of the project's data — in all of its captured, derived, primary, or secondary forms — will eventually be made available to the public, what has been packaged and circulated so far has not been produced for use in research or analysis contexts. Furthermore, because these public facing outputs are primarily designed to *show* and *demonstrate*, they also are defined by a certain opacity. Users are not able to query the data in any quantitative way, nor are they able to access the hundreds (if not thousands) of span points, images, and GPS coordinates from which they are derived. As a result, in order to produce effective models for demonstration, practitioners like Aaron have to be selective about what data to highlight and emphasise:

> It is something that we are getting closer to, showing people the actual geometric information of a recorded model. As I said before, everything is getting more powerful...We aren't faking it in terms of we're not putting fake marks on or painting by hand to show these things. I'm using the information that exists there. I am increasing the contrast and changing the exposure levels to bring out the darker marks to show off where there might be...[interesting] information. But I am not going in by hand, as an uneducated person, and highlighting areas I think might be interesting, it is brought out by the geometry itself, and it is brought out by what we export. So there is an argument for why we want to keep relying on visualisation, for why you show... the edited versions. Because it makes it clear the person looking at it, and

[78] An earlier pan-European digital heritage initaitive with which the Discovery Programme was intimately involved (http://www.3dicons.ie/).



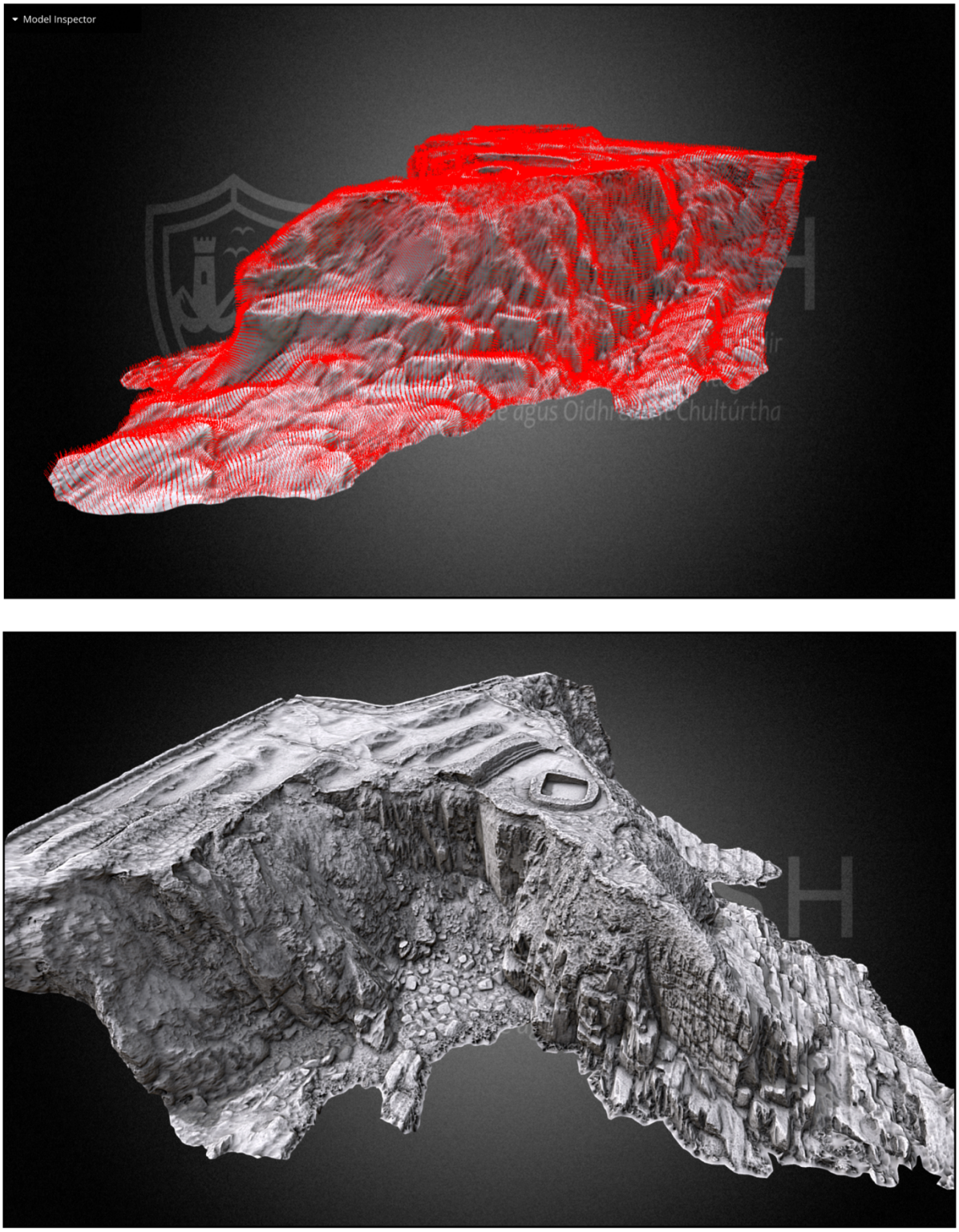
Figures 6.7. *A 3D model of the Hill of Tara in Co. Meath which was derived from a LiDAR survey during Discovery's involvement in the 3D Icons project. This model is notable in that it functions as a dramatically reduced rendering of a dataset that was remarkably large and detailed at the time of its capture. It is now hosted on sketchfab.com.*

Figure 6.8. *(Bottom image) "Orthostat 18", a relic/artefact visualised using ambient occlusion from the western tomb at the Knowth heritage site. These images are here contrasted to provide an example of the relative scales of the data with which Aaron works. Source: models made by Aaron Deevy.*

> possibly even clear to the person who knows exactly what they're looking at, what is and is not there (Aaron Deevy, Interview, Nov. 28, 2018).

These processing decisions are made partially for the sake of the intended user (i.e., in order to emphatically visualise specific features), but they are also necessary because the interfaces ultimately used to visualise such models do not have the capacity to handle the entirety of the data potentially available. Both factors, then, hold considerable bearing over the resulting digital heritage objects.

In order to process complex datasets (like dense point clouds) into viable 3D models, Aaron performs a series of nuanced reformatting procedures using a number of different softwares. These procedures are not as simple as deleting or removing weighty or unnecessary input data while preserving others, but require reconfiguring such data in order to approximate the geometric complexity of the original input while still reducing the size of the resulting model. These procedures included applying "ambient occlusion", "normal mapping", and/or "re-topologising" the resulting models. Ambient occlusion, for example, is a process where hypothetical light values for the polygonal surfaces of a model are individually calculated in order to simulate reflective exposure to artificial or ambient light sources placed within the model's environment. Normal mapping, by contrast, is a process where a new or artificial surface is derived and approximated from the "normal lines" (calculated perpendicular vectors protruding from the centre of each polygon) of the model's surface ((*figures 6.9 and 6.10*). The re-topologisation of models concerns the reconfiguring of the topology of the meshed surface. The wireframe meshes produced within Photoscan are composed of interconnected triangle shaped polygons, with the vertices of each triangle corresponding to a point within the cloud. In order to re-topologise a mesh, these triangle polygons can be re-formatted as different polygonal shapes (such as rectangles), resulting in less intricate surfaces that are in turn easier for rendering softwares to process.



Figures 6.9. *A 3D model of Dunbeg Fort with vertex normals visualised. Vertex normals are produced within viewing interfaces (in this case the viewer on sketchfab.com) in order to visualise the perpendicular lines emanating from the centre of every polygonal surface of a models mesh. Vertex normals can be used to derived simplified surfaces of more complex inputs, thus rendering file size outputs more manageable or mobile.*

Figure 6.10. *(Bottom image), a 3D model of Dunbeg Fort visualised using ambient occlusion. Because ambient occlusion works to specifically visualise reflectance, it can often to be used to assess the contours and shapes of surveyed sites in a way that would be difficult using standard visual imagery. The stark relief produced above, for example, highlights the crevices and degradation caused by the erosion on site. Source: models by Aaron Deevy.*

Despite key differences in how such approaches might reconfigure the input datasets, what they do share in common is based in the principle of reducing the underlying geometric complexity of the inputs while maintaining the appearance of complexity on the *surface* of the 3D form. The practical justification for this lies in ensuring that the desired outputs do not exceed the processing power of workstations and softwares used to render them as models for the public while still maintaining a photorealistic appearance:

> This is one of the high poly models, so that one is triangle [based]. And as you can see there, that area, that's 1.4 million polys. And this is a pretty low count. We've got models that, when they come in at high poly, we try and limit around 20-30 million [polygons]. Because the computer currently can't run higher than that when we are trying to export things. We could have higher numbers if we had the ability...It is just a massive file (Aaron Deevy, Interview, Nov. 28, 2018)

The general feeling among Cherish practitioners is that they will produce more intricate models when that becomes possible. At present, however, the assumed audience and application of these outputs has yet to necessitate more complex, dynamic, or data-rich digital objects. Simply put, as of now, the primary goal of circulating outputs to the public is to stimulate discourse through striking visualisations. Discussing the matter with Robert, while he was quick to confirm that (in the context of analysis) much of the value of the 3D data was couched in its capacity to facilitate the comparisons of outputs from different surveys, there was also a tremendous value in servicing products that simply "looked good" in order to "tell stories":

> [In] presenting the data, the data's...value [is in] comparative studies. Of comparing like to like. But I think it does have [the] value to tell stories, and that's why it has to look good. A lot of the work we are doing is telling stories, I think. There are things we can do with the drones that we couldn't previously do. So, it is maybe changing the way that we package up the end results. There is more to it than just the 3D model and the DSMs [Digital Surface Models] and the orthos [ortho-mosaics]. We can actually use these new techniques that are available, readily available to us, to make things more visually pleasing (Robert Shaw, Interview, Nov. 28, 2018).

The digital objects Cherish produces for the public, then, are not only defined by the softwares and platforms used to visualise them, but by how the assumed use or application of

these objects necessitate their formatting and processing in specific ways. Because the public facing outputs are commonly circulated through browser-based platforms (such as Sketchfab), the resulting models need to not only conform to specific size limitations[79], they need to meet the standards of visualisation the project has set for itself. The project has developed protocols for ensuring these standards, with practitioners like Aaron reliably defaulting to the same configurations of softwares and methodologies to reach these goals[80]. Consequently, to define these outputs as digital objects is to not only consider their file sizes, data-types, or the number of polygons that compose them, but to situate them in the relational configurations assembled to both render them cohesive *and* accessible through specific interfaces.

This is also true when it comes to the outputs Cherish uses for in-house analysis projects. The key difference, however, is in-house digital objects rarely resolve as 3D models. The digital objects practitioners like Robert most often use to quantify land loss are raster-based DEMs (digital elevation models): two-dimensional images rendered from dense point clouds (via either photogrammetry or laser scanning) and analysed in ArcMap[81]. Yet while the outputs Cherish currently uses for the majority of its quantitative analysis work are *not* their 3D objects, it is critical to remember that the accuracy embedded in such products is contingent on their being derived from 3D data. 3D modelling, and the production of dense point clouds in particular, has therefore helped to push the geo-morphological monitoring Cherish undertakes to new levels of accuracy.

[79] A private Sketchfab profile, for instance, has a 50mb limit on uploads and a 200mb limit on professional accounts like Discovery's.
[80] A combination of softwares such known as Geo-magic, Mudbox, and Meshdoctor are frequently used in concert to correct and address aberrations in the polygonal surfaces of wireframe meshes, for example.
[81] ESRI's flagship GIS programme.

This is not to say, however, that Cherish practitioners place a higher analytical premium on 2D outputs (like DEMs) than they do on their 3D outputs. Nor that 3D models have no capacity to be used in such contexts. Given the slope and verticality of many of their sites, it is occasionally not possible to use DEMs to quantify land-loss[82]. Being able to use 3D objects to perform such analysis, however, requires having a repository of frequently updated surveys all registered with the same levels of geo-locative accuracy, a standard Cherish has only been able to achieve with a handful of its sites across the project to date. Furthermore, the project is still in the process of refining a standardised methodology for undertaking such types of analysis. Robert, for one, admitted that transitioning their analysis work from raster-comparison (which he referred to as "2.5D mapping") to work based about 3D objects was an issue he "would have to be honest and say that we do not have the final path on, yet" (Robert Shaw, Interview, May 28, 2019).

As such, there is a distinct way in which dense point clouds prove some of the most central and dynamic of the outputs Cherish has produced and keeps in its database. Dense clouds serve as the foundational input for both the 3D models Aaron uses to render objects for Sketchfab, as well as the DEMs and ortho-mosaics practitioners can use to monitor erosion. Crucially, the value of the dense point clouds is bound up in their potential to continue to serve as outputs as methodologies change and adapt. This dynamic flexibility further evidences both the mutability of the digital objects Cherish produces, as well as their ontological multiplicity. Which is to say that, while Cherish has protocols and processes in place that currently resolve in an output cohesive digital geometric forms with prescribed

[82] Steep changes in grade and slope, for example, inevitably result in stretched pixels and error. It is in such instances that the Discovery programme has begun to experiment with 3D models for analysis purposes. Following a severe collapse at Dunbeg Fort during the winter storms of 2017, for example, the Discovery Programme used Geomagic (an engineering software designed to compute 3D inputs) to contrast 3D models derived from before and after the collapse to quantify the loss. By deducting post-collapse model from the earlier one, they were able to deduce that the site had lost nearly 4.5 thousand tonnes of earth to the sea in one day.

uses and applications, these protocols, processes, and objects are likewise are expected to fluctuate. As such, while the current output of 3D models or DEMs is structured around specific softwares, viewing interfaces, and processing/application methodologies, these components — and the way in which they're alternately assembled in order to render digital objects cohesive — will in turn change and adapt as methods are innovated and technologies improved.

6.4 From Epistemic Things to Technical Objects

As dense clouds are processed into objects like 3D models or digital elevation models, they transition from being composed of thousands (if not millions) of individual points — each with unique coordinate data and colour attributes — into cohesive geometric shapes and singular images, respectively. As a consequence of this objectification, they are not only able to more easily travel across networks and between platforms, but they also become more accessible as tools of either illustration or analysis. Taking a detailed overview of how these objects are derived — from images/scan points to clouds, meshes, and models — the correspondence between the resulting data/digital objects and the performed measurement and observation inherent in their initial production as 'captured' data becomes harder to parse. Early on in the process of photogrammetry, for example, a user can still navigate a sparse point cloud through the primary images and coordinate data from which it is derived. Being able to correlate a digital object (like a sparse, or even dense point cloud) to the captured/"acquired" data upon which they're based preserves the extent to which such objects can be understood as intimate records of the knowledges gained by the people who produced them. In this sense, as long as such correlations can be made or observed, such objects can also be understood as "epistemic things". As these correlations become translated through iterative processing and formalisation, however, these objects are more appropriately

understood as "technical objects". It is a distinction reinforced by the fact that, as processed and formalised tools of illustration or analysis, they're increasingly used to determine and produce new "epistemic things". As it concerns the overarching question of how the archaeological knowledges produced through digital visualisation come to be co-constituted, then, there is a way in which attending to the specific mutability and multiplicity of Cherish's digital objects becomes helpfully instructive. When and how disparate sets of data become associated with one another, and how they are combined and collectively processed to produce coherent models, provides drastically different insights into how such objects and data are produced and how they're capable of being used.

Something this chapter has further established is the correspondence between conditions of relationality (as assemblages) and the ontology of digital objects. It is the assembled relationships between datasets and platforms that render them cohesive as models or images. Foregrounding these relationships — and thinking them through with assemblage theory — further generates a specific question; namely, whether "objects exist and then enter relations" or "are the relations themselves primary" (Fowler and Harris, 2015, pg. 128). It is a debate that has become central to many contemporary discourses on *new materialism*, one which often sees Ingold, Latour, or Harman alternately contrasted towards different ends (Fowler and Harris, 2015; O'Reilly 2018; Latour, 1999; Latour, 2007; Ingold, 2011; Harman, 2018). For archaeologists Chris Fowler and Oliver Harris, this question becomes particularly complicated when considering the *endurance* or propagation of these relational foundations within the material objects or *things* they study:

> One tendency in these approaches is increasingly to see material things as an ever-changing bundle of relations, to emphasise the way they are constantly fluid and in flux. This has helped overcome an older view of material things simply as inert objects, brought to life only through human agency. Yet this response risks preventing us from understanding how material culture comes to endure (Fowler and Harris, 2015, pg. 128).

As scholars focused on the ontologies of objects across a continuum of history, Harris and Fowler are sceptical of theories such as Graham Harman's Object-Oriented Ontology. This is primarily because OOO, in their estimation, is overly bound up in a presumption of "thingness" defining or enabling an entity to enter new relations in the future. As a result, it is their worry that such logics compromise any consideration of how and where past relations cohere into that which might define an object in the present and in the future. And while Fowler and Harris are specifically discussing the relational materiality of physical artefacts, such concerns take on added emphasis when applied to the consideration of the development of digital heritage objects. Digital objects — by virtue of their attendant metadata records, for example — often contain readily accessible records of the relational components that define their respective constitutions. This thesis has established the material engagements with assembled instruments and data, as well the procedural performances undertaken by Cherish practitioners at different sites, as part of the assemblages it has located throughout the Cherish workflow. Furthermore, it has established how these assemblages are central to determining how Cherish datasets both cohere and evolve. The issue, however, is that as Cherish data is iteratively processed and made coherent as formalised digital objects — and technical objects in particular — the evidence or record of these entanglements and assemblages becomes increasingly less detailed and thorough. It is for these very reasons that scholars like Janet Vertisi and Rob Kitchin have made parallel critiques of how scientific visualisations and data are too often circulated or discussed as being self-evident, neutral, or strictly "objective" (Kitchin, 2014b, Vertisi, 2015).

Another way of understanding how Cherish's digital objects transition from "epistemic things" to "technical objects" is to consider both digital heritage objects and the workflows that generate them within Yuk Hui's notions of the "datafication of objects" and the "objectification of data". In specifically addressing the organisational agencies of the

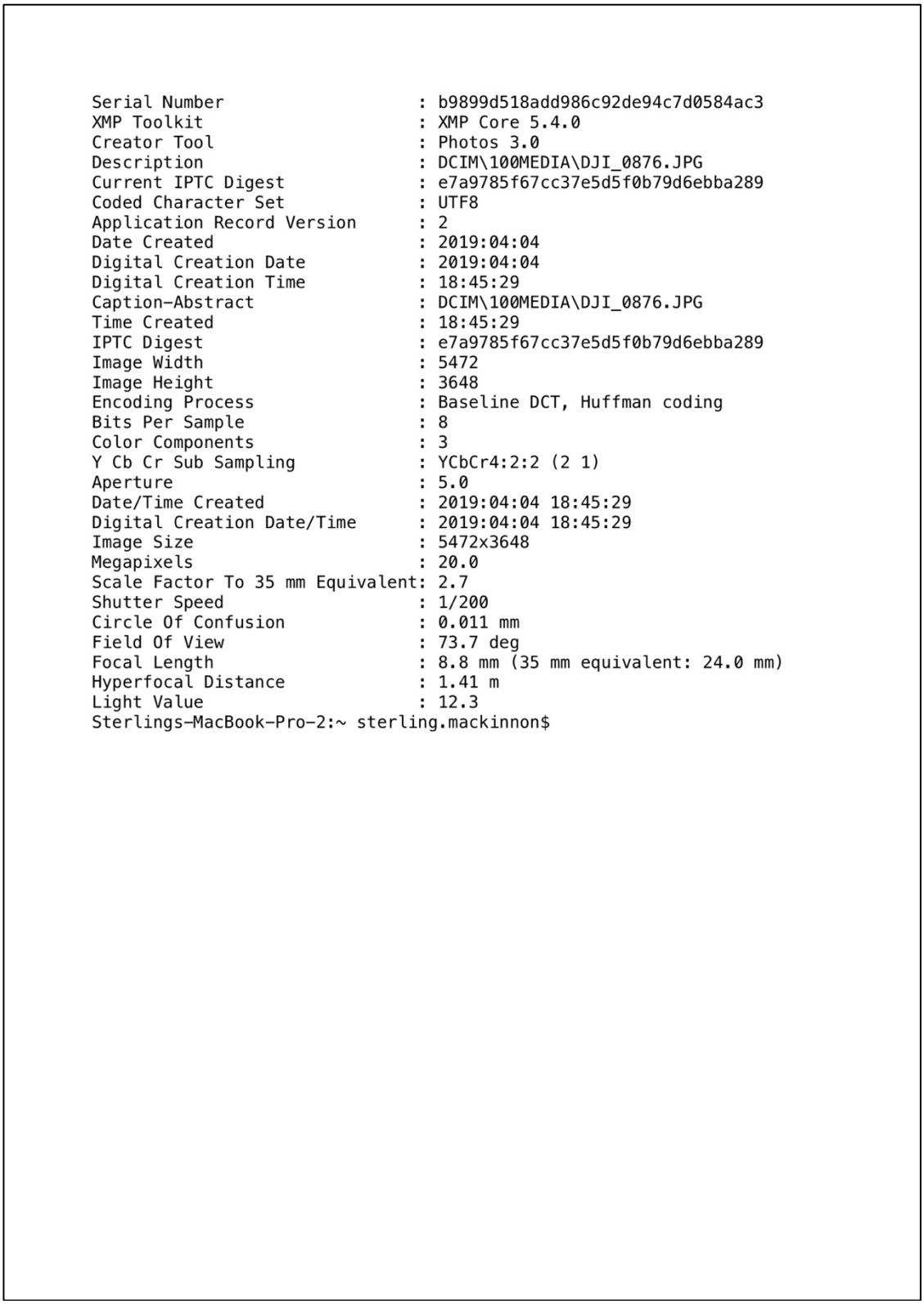
Cherish databases and the assemblages of software used to render cohesive outputs, this chapter has addressed what Hui would describe as the *objectification of data*. The acquisition of data described in Chapter 4 could likewise be discussed in terms of Hui's notion of the *datafication of objects.* In a very direct but admittedly limited sense, it is not difficult to use specific pieces of Cherish data to think the formalisation of digital objects and the enduring and mutable nature of the relationships that define them together. Take, for example, any image (likely a .jpeg file) generated during a drone survey. This image can be processed using an EXIF tool[83], an application capable of generating a detailed report of the metadata inscribed within a specific digital image. For example, the image DJI-0876 (*figure 6.11*), is one of the several hundred images Robert produced while conducting drone survey at Dunbeg Fort. It is an oblique image, meaning that it was taken while Robert was piloting the drone and was not automated using the DJI ground station app. Once processed by the ExifTool, the application produces a detailed report (*figures 6.12 and 6.13).* Here, you can find details ranging from timestamps, focal lengths, exposure levels, f/stops, and more. All of which, when considered in concert with the geo-referenced data attached to the entire Dunbeg survey, comprises a detailed annotation of some the conditions and contingencies associated with the *event* of producing this specific image. What is important to consider, however, is the extent to which even this slight and metricised overview of the process is accessible within certain iterations of a photogrammetry project and absent in others. As Cherish data is translated from sets of images to point clouds, from point clouds to surfaces, from surfaces to re-topologised surfaces, and so on, this detail is lost. It would be remarkably difficult, for example, to trace the relational assemblages inherent to a digital object such as

[83] Numerous free EXIF tools are available across the internet. The examples produced for this chapter were generated using "ExifTool by Phil Harvey", which is available for download here: https://exiftool.org/.



Figure 6.11. *Image "DJI-0876". Source: one of the 256 images taken by Robert Shaw at Dunbeg Fort on April 4, 2019.*

```
File Name                       : DJI_0876.jpg
Directory                       : /Users/sterling.mackinnon/Desktop
File Size                       : 7.2 MB
File Modification Date/Time     : 2019:06:16 19:17:14+01:00
File Access Date/Time           : 2019:06:16 19:17:44+01:00
File Inode Change Date/Time     : 2019:06:16 19:17:16+01:00
File Permissions                : rw-r--r--
File Type                       : JPEG
File Type Extension             : jpg
MIME Type                       : image/jpeg
JFIF Version                    : 1.01
Exif Byte Order                 : Big-endian (Motorola, MM)
Image Description               : DCIM\100MEDIA\DJI_0876.JPG
Make                            : DJI
Camera Model Name               : FC6310
X Resolution                    : 72
Y Resolution                    : 72
Resolution Unit                 : inches
Software                        : Photos 3.0
Modify Date                     : 2019:04:04 18:45:29
Exposure Time                   : 1/200
F Number                        : 5.0
Exposure Program                : Program AE
ISO                             : 100
Exif Version                    : 0230
Date/Time Original              : 2019:04:04 18:45:29
Create Date                     : 2019:04:04 18:45:29
Components Configuration        : -, Cr, Cb, Y
Compressed Bits Per Pixel       : 3.223040505
Shutter Speed Value             : 1/200
Aperture Value                  : 5.0
Exposure Compensation           : 0
Max Aperture Value              : 2.8
Subject Distance                : 0 m
Metering Mode                   : Center-weighted average
Light Source                    : Daylight
Flash                           : No flash function
Focal Length                    : 8.8 mm
Flashpix Version                : 0010
Color Space                     : sRGB
Exif Image Width                : 5472
Exif Image Height               : 3648
Exposure Index                  : 0
File Source                     : Digital Camera
Scene Type                      : Directly photographed
Custom Rendered                 : Normal
Exposure Mode                   : Auto
White Balance                   : Auto
Digital Zoom Ratio              : 0
Focal Length In 35mm Format     : 24 mm
Scene Capture Type              : Standard
Gain Control                    : None
Contrast                        : Normal
Saturation                      : Normal
Sharpness                       : Hard
Subject Distance Range          : Unknown
```



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Serial Number                    : b9899d518add986c92de94c7d0584ac3
XMP Toolkit                      : XMP Core 5.4.0
Creator Tool                     : Photos 3.0
Description                      : DCIM\100MEDIA\DJI_0876.JPG
Current IPTC Digest              : e7a9785f67cc37e5d5f0b79d6ebba289
Coded Character Set              : UTF8
Application Record Version       : 2
Date Created                     : 2019:04:04
Digital Creation Date            : 2019:04:04
Digital Creation Time            : 18:45:29
Caption-Abstract                 : DCIM\100MEDIA\DJI_0876.JPG
Time Created                     : 18:45:29
IPTC Digest                      : e7a9785f67cc37e5d5f0b79d6ebba289
Image Width                      : 5472
Image Height                     : 3648
Encoding Process                 : Baseline DCT, Huffman coding
Bits Per Sample                  : 8
Color Components                 : 3
Y Cb Cr Sub Sampling             : YCbCr4:2:2 (2 1)
Aperture                         : 5.0
Date/Time Created                : 2019:04:04 18:45:29
Digital Creation Date/Time       : 2019:04:04 18:45:29
Image Size                       : 5472x3648
Megapixels                       : 20.0
Scale Factor To 35 mm Equivalent: 2.7
Shutter Speed                    : 1/200
Circle Of Confusion              : 0.011 mm
Field Of View                    : 73.7 deg
Focal Length                     : 8.8 mm (35 mm equivalent: 24.0 mm)
Hyperfocal Distance              : 1.41 m
Light Value                      : 12.3
Sterlings-MacBook-Pro-2:~ sterling.mackinnon$
```

Figures 6.12 and 6.13. *The metadata report I generated for image DJI-0876.jpeg using an exif tool. In both the image above and in the one on the page previous numerous details about the acquisition of this specific piece of data are detailed. The time of day the image was taken, for example, or the make and model of the camera mounted to the drone. More importantly, however, are the inscriptions of details such as image resolution, focal lengths and more. Taken collectively, such metadata provides a partial window into the numerous components assembled to produce this image. Source: Exif reports produced by author.*

the digital elevation models Robert produced from this survey unless it came deliberately and explicitly annotated in specific or novel ways.

Cherish practitioners have only just begun to use what they are calling "event logs" to enrich and annotate surveys. Yet it is worth noting that these event logs are not produced with any potential users in mind; they are not directly attached or accessible through final visualisations or applied articulations produced through the project. All of this points to something of a conundrum. Yuk Hui, for instance, has contended that digital objects "are data objects formalised by metadata and metadata schemes, which could be roughly understood as ontologies" (Hui, 2016, pg. 26). Yet in the context of the Cherish Project and the objects they've so far produced, metadata isn't exhaustive. It doesn't "endure" in quite the way Fowler and Harris mean. It is compromised by the iterative re-processing of data as it is subjected to the series of translations that eventually render digital objects with practical use and value. Furthermore, much as Redström and Wiltse contend that "networked computational things combine a range of technologies, computation, communication, sensors, interfaces, etc. to become what they are", a digital object — in and of itself — can often become a rather opaque "thing" (Redström and Wiltse, 2019, pg. 67). Its constitutional components are difficult to find and often harder to read. There is a distinct way in which Cherish's iterative development of its data from "epistemic things" to "technical objects" cannot be traced by following the metadata attached to the data at different stages because that data has been removed. This, in turn, serves as a further justification for the research of this thesis. Because the reverse engineering of digital heritage objects is often not possible, tracing their production from stages of acquisition onwards becomes necessary to understand just what they are.

6.5 Conclusion

In one respect, acknowledging the configurational arrangement of components inherent to the coherence of data objects changes how we might understand just what a digital heritage object *is* and, by extension, what it can *do*. Anna Munster and Adrian Mackenzie's recent scholarship on "*platform seeing*" is useful here. It suggests that we might see the relationship between a Cherish object's basis in hundreds (if not thousands or millions) of itemised digital images/coordinates and its status as an object as predicated on conditions of networked relationality organised around the functionality of attendant softwares and platforms (Munster and Mackenzie, 2017). Johan Redström and Heather Wiltse have likewise posited that the "scope of possible actions and effects" of a digital or computational "*thing*" is determined by "the topology of the network in which it is part" (Redsröm and Wiltse, 2019, pg. 14). Cherish and its object-based outputs, then, can similarly be assessed by attending to the relational configuration of the components assembled in both their production and interfacing.

This chapter has explored the correspondence between distinct relational configurations and object coherence in two key contexts; the Cherish database and the co-functioning of softwares and platforms commonly used to render models. The Cherish databases function not only as repositories for the project's digital outputs, but as the primary means through which these datasets are categorically organised. To date, both the Discovery Programme and RCAHMW's respective databases are expanding as the project continues to evolve, meaning that these databases have been designed or structured in order to optimise the enactment of current visualisation and modelling projects while also anticipating the data's potential for future applications. (This is why all photographic datasets are duplicated and organised as either "raw" or "working" images). This indexical system of storage and organisation further serves as the means through which datasets initially become tagged with meaning. Identical data types — such digital photographs (.jpeg files) or coordinate tables

(.xls files) — by virtue of their organisation within the database develop meaningful relationships and associations with other datasets filed or categorised in similar ways. The result of this indexing and structuring, this chapter has shown, is the distinct potential Cherish databases possess to formalise and differentiate Cherish data as digital objects at different stages and with different potentials for application outside of the assemblages that defined their acquisition and processing.

This chapter has also addressed the correspondence between specific visualisation softwares/platforms and the coherence of Cherish objects. Particularly as it concerns the limitations of the interfaces and platforms ultimately used to visualise "finished" Cherish models, the assembling of different softwares is here described as a process of refinement facilitated through the systematic reduction of input datasets. Here the structural or geometric complexity of the dense point clouds and wireframe meshes (inputs) are reduced and simplified while the surfaces and textures of the outputs are elaborated and reconfigured to preserve the appearance of detail and complexity. Given that the prescribed uses of these outputs (in contexts of analyses or illustration) are serviced rather than compromised by these procedures, what's evidenced is how it is also the respective capacity of given visualisation platforms or interfaces to 'read' or 'handle' Cherish's outputs that dictates how Cherish objects are constituted and organised. As a result, the cohesion of Cherish objects is further described as a consequence of the configurational relationships assembled through the fitting together of softwares, platforms, interfaces, and intended or projected uses.

As Cherish data travels to and from its parent databases and is subjected to these procedures of refinement, the data are changed and altered significantly. As such, something this chapter has further established is the degree to which the metadata schemes inscribed into Cherish data at sites of either acquisition or processing (Chapters 4 and 5, respectively) remain legible within the objects the Cherish workflow produces.

Particularly as it concerns how this thesis has sought to define Cherish's digital outputs as both "epistemic things" and "technical objects", the formalisation of digital objects facilitated either through methods of indexical storage or the production of models is here established as the primary means through which such valences are determined. Particularly as Cherish outputs are put towards efforts of analysis or demonstration, the "objects" best described as records of the intimate knowledge its modeller gained during its production–i.e., the data most detailed and annotated with geo-locative and visual information, the "raw" images, clouds composed of thousands or millions of individual points — transition into models with discrete functions or purposes. What's been revealed, however, is the degree to which this transition emphatically changes this record of knowledges while simultaneously coming to figure in new knowledge-producing contexts or situations. To quote Natasha Myers:

> An epistemic thing remains elusive and unknown; it is not quite yet within the grasp of the scientist and it has not yet solidified into an object. A technical object may at one time have been an epistemic thing, but once elucidated it could be put to the task of determining other epistemic things (Myers, 2016, pg. 79).

How, then, do these technical objects relate to the assemblages that produced them? Their emergence, this thesis has shown, is directly related to the co-functioning of the many components assembled towards their production. And yet, by virtue of their context-specific formalisation, these objects are less defined by the relational assemblages that produced them, but more by the assemblages that render them visible and accessible to users. In fact, it is Myers' implication that their capacity to function in new knowledge-producing endeavours is predicated on their ceasing to function as "epistemic things". After DeLanda, one could say that both the formalisation of Cherish data as technical objects *and* their capacity to enter into new knowledge producing assemblages is predicated on their not being "totalised" by the assemblages that originally produced them. The models the Cherish project has already produced — and will continue to produce — are dynamic and powerful; they constitute the

robust baseline of 3D geomatic data the project is developing for the planning and management of coastal heritage landscapes critically threatened by climate change. However, if their potential for application is so thoroughly bound up in their cohesion as technical objects — and if the conditions of cohesion render these objects as opaque in the ways described within this chapter — the processual assembling of the knowledges that co-constitute them will often be obscured and compromised by the time they are applied in the contexts for which they've been principally produced.

Chapter 7: Conclusion

While the project has several years left on its charter (particularly because of the unforeseen delay caused by the COVID-19 pandemic), Cherish has already begun to circulate its finished and formalised models and visual products. A selection of their 3D models is already hosted on Sketchfab.com, where users can interact with photo-realistic and cm-scale accurate renderings of sites like Dunbeg Fort in various stages of collapse. Cherish primarily uses these models as outreach tools; that is, as a means to engage the public in conversations about heritage conservation, preservation, and future monitoring. Cherish investigators like Robert, Anthony, and Toby also frequently present their research at symposia and conferences across the UK and Ireland, where outputs like models, DEMs, and ortho-mosaics enable them to illustrate the dynamic and innovative approaches to survey and visualisation they are developing through Cherish. Finally, the Cherish Project also uses their formalised outputs in-office to conduct geo-morphological analysis. As has been established in Chapter 6, these outputs arrive as tools for application as "technical objects". Which is to say that, as tools of analysis, outreach, or interpretive learning, they are capable of facilitating epistemic work and of entering new knowledge producing assemblages. In order to become technical objects, however, they necessarily cease to function as 'epistemic things'. In the examples listed above, these models and visual products arrive on screens and interfaces as drastically compressed files, as slides in PowerPoint presentations, and as raster files capable of being contrasted and analysed in softwares such as ArcMap, for example. By the time these outputs are put to use, they have been developed from collections of digital images totalling in the thousands, to point clouds composed of millions of individual units, to 3D wire frame meshes and polygonal surfaces that are often ultimately visualised again as two-dimensional images. Throughout these iterative translations, Cherish data are refined and dramatically altered, a process which this thesis has also demonstrated results in the refinement of metadata, or, after Rob Kitchin, the primary means through which the provenance of given dataset's production

remains inscribed and attached as it iteratively develops (Kitchin, 2014b). Following Karen Barad's claim that scientific images are "condensations or traces of multiple practices of engagement", then, this thesis has further shown how the development of heritage data from epistemic things to technical objects means these traces are rendered inaccessible and hard to read by the time they are formalised as research tools (Barad, 2007, pg. 53). In short, while we can understand how digital heritage objects function as tools of analysis or research, it's far more difficult to grasp what they *are.* The digital mediation of heritage is becoming increasingly pervasive. Given digital heritage objects' distinct capacity to be applied in the conservation and preservation of heritage sites that are either threatened or disappearing, the imperative to critically theorise them has only grown more pronounced.

This research began by asking the central research question: *how do the knowledges carried by digital heritage visualisations come to be constituted?* In using the theories this thesis has assembled as well as the methodological toolkit employed in the field, it has traced the Cherish Project's production of digital heritage visualisations via UAV survey, laser scanning, and walkover survey. In so doing, the thesis has also addressed the attendant research questions of *how digital heritage data are produced at field sites, how these data move between sites of production,* and *how these data comes to cohere as digital heritage objects.* It has used these subsequent questions to structurally organise my empirical findings around the topics of data acquisition, data processing, and digital heritage object coherence. It has described how the initial derivation of modelling data is predicated on both the assembling of "sites of acquisition" and the production of spatial registers inherent to the enactment of such work. Following the data to secondary stages of processing and visualisation, what is further revealed is the degree to which the development of datasets acquired in the field is predicated on translating and synthesising both the geo-locative and visual data into densely relational geometric configurations. Furthermore, this process has

been shown to be generative of both multiplicities of digital objects and the new context-specific spatialities associated with them. Finally, the thesis has traced the formalisation of Cherish objects as being contingent on the relational configurations facilitated through their method of data storage/organisation, the agencies of the softwares and platforms used to render them for specific applications, and expectations about their uses and users. These final processes — by virtue of the reduction and reconfiguration they require — are instrumental in changing the digital objects the project produces from "epistemic things" to "technical objects". Taken collectively, this thesis has demonstrated that the knowledges carried by digital heritage visualisations come to be constituted via complex networks of circulating reference dispersed across multiple sites of activity. It has defined these sites as being situationally assembled via the fitting together of practiced expertise, technologies, and the unique characteristics of the sites and monuments digitised. As heritage data move, develop, and cohere as digital objects, these assembled situated knowledges are subjected to iterative translations. These translations, it has shown, facilitate the formalisation of heritage data, changing them from epistemic records of knowledge acquired to research tools with distinct applications.

The fitting-together of theory and method detailed above is also indicative of the contributions this thesis makes to existing geographical and archaeological discourses more generally. Archaeological discussions on *new materialism, assemblage theory,* or *relational realisms*, for example, have found innovative articulation since the 1980s (Hodder, 1982; Hodder, 1997; Hamilakis, 2017; Hamilakis and Jones, 2017; Fowler, 2013; Fowler and Harris, 2015; Lucas, 2012). Yet the development of such concepts has been dogged by the persistent gap between the theories proposed and their respective potential for application in methodological practice. In following a research initiative such as Cherish, this thesis directly

situates such theory within the context of applied archaeological practice. In contrasting concepts like agential realism with media theorists like Yuk Hui or Rob Kitchin, for example, it traces crucial relationships between the situated *doing* of archaeology and that which emerges through the enactment of such work (namely data and digital objects). This is particularly important considering the extent to which both archaeology and heritage sciences continue to orient their practices around digital mediations of heritage.

Human geographers, by contrast, are still in the process of developing effective tools for analysing and theorising digital visual cultural objects (Rose, 2016a). Within topics such as "big data" and "smart cities", for example, select scholars and theorists have begun to address how digital images or the visual expression of networked data relate to our understandings and experiences of imagined urban futures, and governance (Batty, 2017; Mattern, 2017; Kitchen et al., 2017; Rose and Willis, 2019; Munster, 2013). The issue, however, is that such discourse is rarely explicitly focused on the production, mobility, and mutability of such images, nor on how such factors come to address the larger questions their research might ask. Discourse in "critical cartographies" has likewise grown increasingly structured around discussions of the digital-visual, particularly as the very notion of mapping becomes increasingly associated with the participatory and performed generation of spatial and visual data by users on mobile devices (Wilmott, 2017; Wilmott, 2020; Elwood, 2010). Here, however, the focus is almost always grounded in discussions of images and visualisations as cartographic tools or products. Furthermore, regardless of focus of topic area, geographers rarely discuss the *digital objects* produced through practices of digital visual spatialisation.

This thesis not only provides a detailed account of how the production of digital visualisations is inextricably bound to notions of multisited-ness and the ontological multiplicity, but how the sites of production and digital objects inherent to such work are

further centred on the mobility and translation of situationally assembled environments, landscapes, and spatialities. Furthermore, in its discussion of digital heritage objects, this thesis develops novel understandings of the relationships between cartographic data and the derivation of cultural objects that are decidedly *not* maps. Across all the methods here observed, it has demonstrated just how bound digital mediations of heritage are to metrics of location and position. Whether we are discussing the 3D models Cherish hosts on Sketchfab, the DEMs they use in-office, or the slides and images they circulate at conferences and lectures, the geo-spatial aspects of digital visualisation have dramatically changed how we see and engage with heritage sites and objects.

Tracing the iterative development of digital objects across sites of production has enabled me to address the epistemic consequences of translating the archaeological record into digital contexts in several ways. For one, in following the inscription, translation, and coherence of the unique spatialities inherent to the work it describes, it has effectively pointed to the situated and relational contexts through which Cherish is producing archaeological knowledges. As it relates to ontological questions, the emphasis this thesis has placed on the derivation and formalisation of digital objects has helped to characterise the Cherish output as being composed of dynamic, multiple, and uniquely relational *things*. To broaden, elaborate, and conclude these findings, however, I'd like to take us back to the field, as it were.

In August of 2019 I returned to Wales – this time to Caernarfon, where Daniel Hunt (from the RCAHMW) and Edward Pollard (from Discovery) had set up a temporary base for two weeks of active excavation at Dinas Dinlle. Dinas Dinlle, like Dunbeg Fort in Co. Kerry, is one of the Cherish Project's flagship sites; it is massive, well-known, and critically threatened by a rapidly eroding cliff face (*figure 7.1)* (Archaeology at the edge!, 2020). It is also — in addition to being the most regularly surveyed and modelled site within the



Figure 7.1. *An aerial photograph of Dinas Dinlle taken on a prospection flight in the early days of the Cherish Project. As is obvious from image, the earthworks present at the site are clearly evident and well preserved. The local area is partially centred around tourism to the site. Equally apparent is the erosion occurring on the western face of the headland. The decision to both commission geo-physical survey for Dinas Dinlle and eventually undertake full scale excavation at the site was made in response to the rapid and time sensitive erosion of possible features buried around the headland. Source: photograph by Toby Driver.*



Figure 02: Trench and Resistivity Survey Location Map superimposed on Geophysical Magnetometer Survey interpretation plan (Hopewell, 2018: 09).

Figure 7.2. *A geo-physics report overlaying resistivity and magnetometry returns for Dinas Dinlle. The RCAHMW had commissioned surveys of Dinas early in 2019. I had first seen this report on my first visit to Aberystwyth in March of that year. The image above was taken while on-site during the excavation. The dark grey features outlined in the print out indicate areas of possible archaeological evidence. As such, they were instrumental to both the RCAHMW and the Gwynedd Archaeological Trust in deciding where to begin digging. Source: photograph by author.*

RCAHMW's remit for Cherish — one of very few sites within the entire project that has been subjected to each of the four levels of methodological investigation outlined in Daniel's upside-down pyramid (see Chapter 4, pg. 88). I'd been familiarised with the site from the outset of my interactions with the Welsh team; Daniel had used photogrammetry files saved at iterative stages from different surveys of Dinas to introduce his approach to visualisation methods, for example. On a different visit to Aberystwyth, Toby had excitedly shared the returns from some resistivity-based geo-physical survey[84] the project had completed at the site (*figure 7.2)*. Having undergone the preliminary prospection inherent in the first tier of investigative methods (aerial photography, etc.), the rough documentation of key features inherent in the second tier (aerial mapping), the increasingly fine-grained documentation of the survey methods grouped within the third tier (UAV survey, Analytic Walkover Earthwork Survey), the RCAHWM concluded that Dinas Dinlle was well worth excavating. My interest in visiting the Dinas excavation, then, was grounded in the fact that the choice to excavate was presented as being densely related to the enactment of the methods and protocols already conducted. Put another way, the very act of digging — of exhuming artefacts and features covered with earth — was likewise framed as a knowledge-producing endeavour that had emerged through the assembling of months (if not years) of complementary (and largely digital) surveys. The excavation was also slated to coincide with a community outreach day, at which the RCAHMW would unveil its first 3D printed model (derived from UAV surveys). I left for Dinas Dinlle, then, intending to observe how the Cherish Project (and, by extension, its performed methodologies) not only resolved in further re-engagements with the heritage landscapes they had originally targeted, but how Cherish's digital methods might change how they could interface with an interested or concerned public audience.

[84] See glossary.

After collecting me from Bangor train station, Daniel drove us to straight to the site, already 3 days into its excavation. Dinas, he explained, was formed by a glacial moraine that would eventually become an Iron Age settlement (likely around 500 BC), with further evidence of Roman settlement occurring centuries later. Climbing the face of the western beachhead, Daniel pointed out the obvious examples of wind and water erosion, including the massive collapse that had occurred earlier in the winter of that year (2019). Once on level land, we began exploring the 7 trenches being excavated, beginning with the two on the Dinas' prominent headland. The first we visited, trench TR01 — already dug to a depth of about 1.5m — revealed two parallel features which appeared like the tops of the walls of a stone roundhouse (*figure 7.3)*. The size and orientation of these protruding features were the topic of much discussion between the assembled practitioners; if the parallel structures were, in fact, part of one circular wall, it would likely be the largest roundhouse ever exhumed in Wales[85] (*figure 7.4)*.

Gazing into these trenches, I found myself meditating on the archaeological term "sondage". Commonly defined as a test excavation, or a smaller area of investigation carved to a greater depth within an already excavated trench, sondages function like windows through which investigators assess where and how to continue in their digging. In order to more efficiently pursue the digging at trench TR01, for example, the teams[86] assembled at Dinas Dinlle has already dug neatly edged 1m x .5m frames in key places around the principal walled features, testing to see just how far down they would go, or how structurally sound their finds actually were. Staring at these tiny trenches, I began to consider the entire Cherish workflow as its own system of 'sondages'. I began, too, to reflect again on Daniel's upside-down pyramid model, particularly the interrelated arrangement of methodologies,

[85] By the conclusion of the excavation, this fact had been confirmed. See figure 7.4 for a visual rendering of what the roundhouse had likely looked like.
[86] It should be noted here that the practitioners gathered at Dinas Dinlle were both from the Cherish project as well as the Gwynedd archaeological trust.



Figure 7.3. *The tops of what are presumed to be the outer walling of a stone roundhouse protruding from the dirt at trench TR01. This image was taken on the fourth day of excavation in August, 2019. By the end of the time allotted for the excavation, the teams digging managed to further unearth close to a metre more of each wall. The trench remained in this state until the open day, where visitors could come and get a look at the find. Ultimately, however, the trench was re-filled. Source: photograph by author.*



Figure 7.4. *In a news update posted on their website following the excavation of Dinas Dinlle , the Cherish project included this graphic rendering of what the stone roundhouses unearthed at trench TR01 would have looked like during periods of Roman occupation (Roman pottery shards have also been found in the areas surrounding the monuments). Source: drawing by Toby Driver, ("News: Historic excavation at Dinas Dinlle", 2019).*

scales of targeted sites, and the fluctuating personnel required for each task that it describes. From aerial photography to UAV survey, from walkover survey to geo-physical survey, the scale of the sites assembled by these methods becomes increasingly more finely grained as Cherish moves from tier 1 methods to tier 4 methods. Furthermore, as the areas of survey become more refined, the datasets acquired through each respective method become inversely more elaborate. A single flight for Toby's aerial reconnaissance, for example, might resolve in several hundred photographs of 10 or more prospective sites covering an area totalling hundreds of square kilometres. Daniel's first UAV survey of Dinas, by contrast, resolved in 1300 images and dense clouds composed of millions of individual points, all for a solitary site. Finally, if and when the collective workflow arrives at the proper excavation of a targeted site — such as it had with Dinas Dinlle — the entire process can resolve in 7 individual trenches — each 20m long and 2m wide — with roughly 15 to 20 practitioners and volunteers there to dig, all now working with earth and stone and artefact more so than with data. This very excavation, it seemed, had emerged through iterative co-functioning and relational assembling of the multiple situated digital methodologies pursued up to this point. Its context, its aims, its methods, the practitioners it had now convened — taken collectively, the new knowledge-producing assemblages that had gathered around it — appeared as relational extensions of the situated work that had proceeded it.

This all crystalised on the 4th day of my visit, when the site and excavation were made open to the public. Guests would register for guided tours of the trenches at the foot of the hillfort, where the Cherish team had erected a visitor’s tent and kiosk. Here the tables were decked with Cherish programme literature, as well Cherish branded pens and keychains. The true novelty at this makeshift welcome centre, however, was the 3D model of Dinas Dinlle that the RCAHMW had recently commissioned from ThinkSee3D, a 3D printing studio located near Oxford that specialises in heritage sector clients (*figure 7.5)*. Also on

display were a series of 3D printed models of palaeolithic pollen spores which the Cherish partners from the University of Aberystwyth had brought along. These models, when contrasted with the Dinas model, had been scaled-up in size by a factor of thousands. The characteristic which united them, however, was their respective capacity for rendering objects of interest/study visible at scales that would otherwise be inaccessible to the naked eye. The efficacy of these models as teaching tools — and the Dinas model in particular — became almost immediately evident. As guests arrived and registered, the model was repeatedly used by Cherish practitioners as a means to field questions about the sources and movement of groundwater underneath the headland, the locations of active erosion areas, past collapses, and orientation of the finds already excavated in the past week. For both practitioner and guest, it was clear that the model enabled them to more easily conceptualise Dinas as a discrete landform with interlocking geological, ecological, and archaeological dynamics. The guests frequently asked to touch the model, which seemed particularly helpful or instructive when discussing the volatile morphology of the site (*figure 7.6*).

A great deal of discussion with visitors was also just about how the model was made. There was a palpable curiosity surrounding the novelty of its production. What was striking about these conversations was how the parallel discussions the model produced — of the site, the dig, and the ongoing work Cherish does — were all facilitated through the same object. Toby, for one, handled the model with considerable excitement, often beginning his conversations with visitors by explaining that it was made with drones and derived from digital imagery. He was particularly keen to emphasise the detail of its resolution. As such, Toby used the model to simultaneously explicate the tour the visitors were about to take—pointing out the locations of the trenches, the zones of serious erosion, etc.—as well as the ongoing survey work Cherish had brought to Dinas and the resulting baseline dataset it is

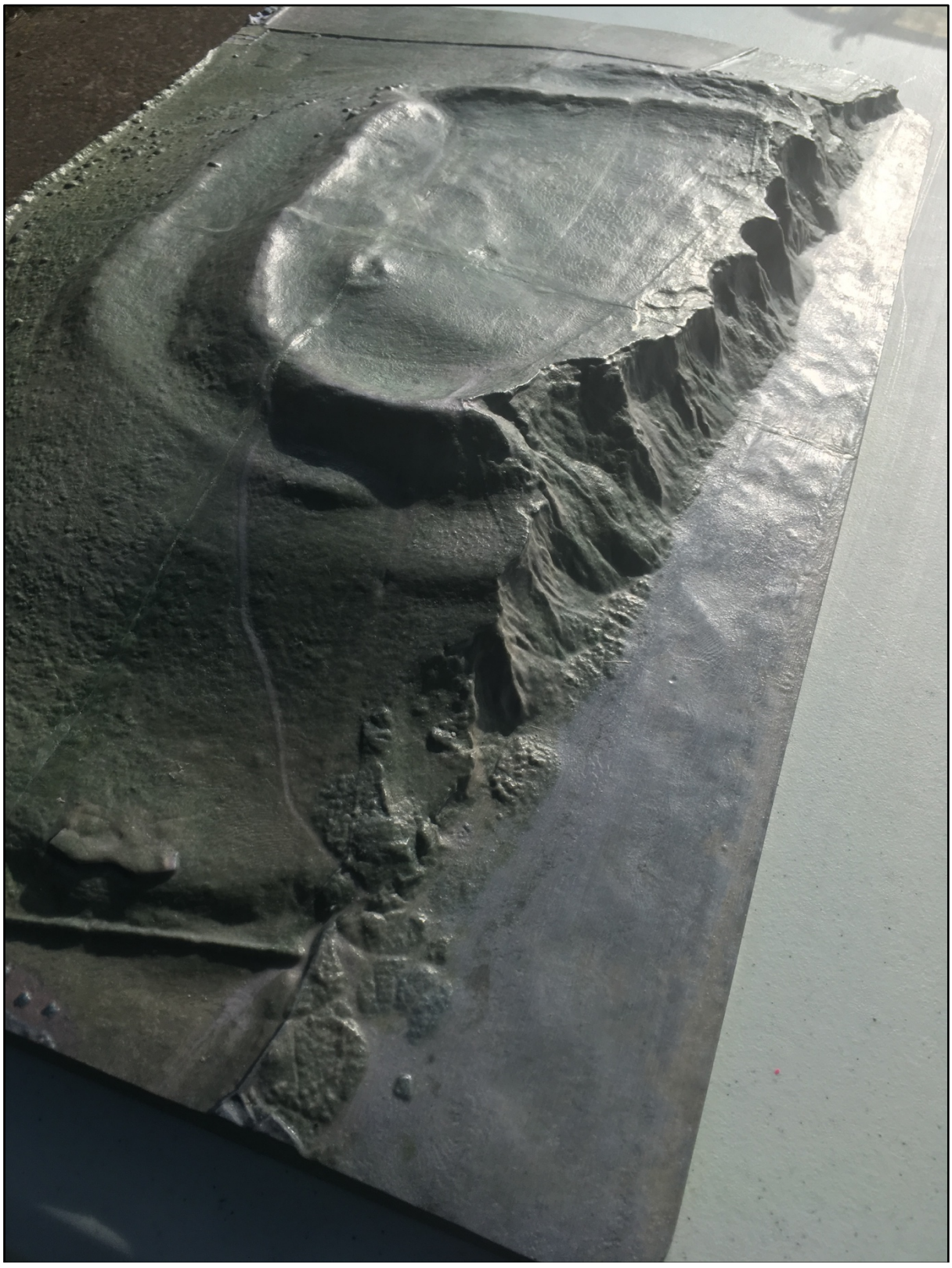


Figure 7.5. *The scale-accurate model of Dinas Dinlle the RCAHMW commissioned through ThinkSee3D. This particular model was a mock-up of what ThinkSee3D would ultimately produce for the commission. Aspects such as the visible seam lines and muted colouring were improved in future printings. For the purposes of the open day, however, this edition worked quite well. This mock-up was later donated to the local historical society by the RCAHWM. Source: photograph by author.*

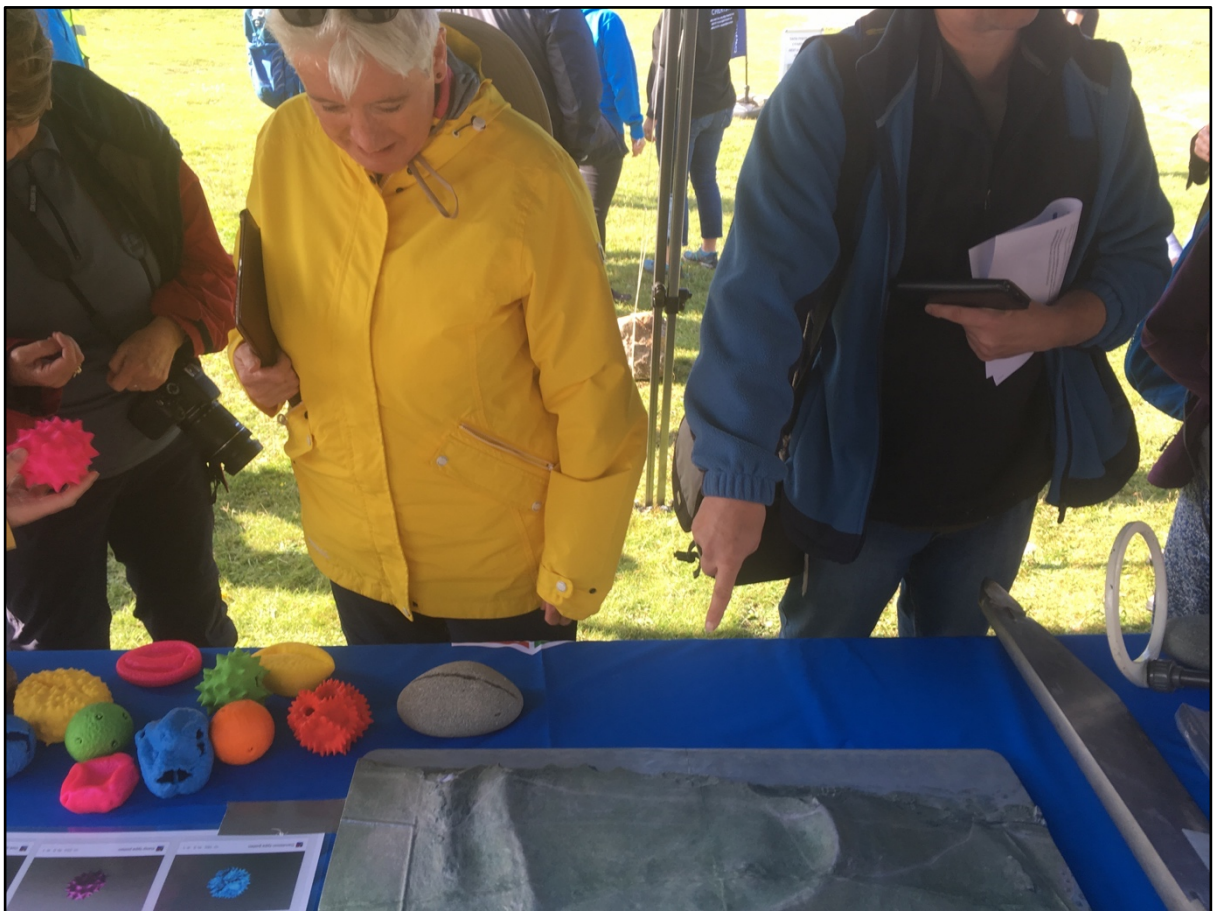


Figure 7.6. *The model on display in the welcome tent at the Dinas open day. Here, the Dinas model was displayed next to the 3D printed paleo-era pollen samples the Cherish partners from Aberystwyth University had also brought along. As is evident in the picture, many visitors at the open day were excited to engage with these printed materials and were particularly keen to touch and handle the prints as practitioners like Daniel and Toby briefed them ahead of their guided site tours. Source: photograph by author.*

continually producing. It was easy to observe just how effective the printed Dinas model could be for justifying the project and inspiring further interest in Cherish more generally.

Without consciously or explicitly addressing them, it was further fascinating to observe how Toby's tutorials managed to touch upon the core themes this thesis takes up; how the field data is produced through assembling of technologies and expertise, how this data becomes multi-sited and iterative by virtue of its travelling from Dinas to Aberystwyth to be rendered, how the 3D printed model itself is a cohesive but uniquely configurational articulation of these various datasets and procedures. In many respects, too, these tutorials — these interchanges centred around the 3D print — narrated how the data Cherish produces travels and changes from epistemic things to technical objects. Perhaps most significantly, however, was the degree to which these demonstrations were actively reconfiguring and recontextualising how visitors would now engage with the landscape they were about to tour. As a technical object comprised of datasets that were once many epistemic things, the printed model was now convening a new type of assemblage; one composed of a physical landscape, a model of that landscape, Cherish practitioners, and an interested community of visitors. As such, what I observed this new assemblage producing were new and dynamic ways of conceptualising and relating to the Dinas Dinlle landscape. As became evident in my own conversations with the visitors, the site was clearly coming to hang together as multiple things at once: as an active and natural geological feature experiencing volatile morphological change, a place of immense historical importance, and something of a laboratory for the Cherish Project, where new and exciting methodological approaches for digitally engaging the intersection of these dynamics were being explored.

Both as the end of my fieldwork and as the conclusion of this thesis, my time at Dinas Dinlle allowed me to return to the central aim of my project; namely, the epistemic and ontological consequences of producing the "archaeological record" as situated digital

mediations. At Dinas Dinlle I found these consequences expressed in two distinct ways. On the one hand, both the methods of investigation and subsequent data/findings produced through excavation demonstrably correlated to both the enactment of many of the procedures this thesis has described, as well as the data and digital objects such procedures had already produced. The choice to excavate at all, the specific locations for trenches, even the ability to convene participants both from within and beyond Cherish (such as the Gwynedd Archaeological Trust), had all been facilitated by the production, translation, and circulation of key digital visual datasets. The entire epistemological bent of the Cherish Project — both as it is still being pursued *and* particularly as it has been designed to extend into the future (via the continued management and monitoring of these sites, for example) — has been shaped by the digital visualising methods Cherish employs. Considering the ontologies of the objects Cherish can produce, it was also clear that the project was geared towards the generation of a repository of technical objects with applications for both teaching and analysis. These objects, these discrete and tangible forms, have taken shape both as "digital objects" and physical objects like the printed model unveiled during the community day (which, in and of itself, is just another way of expressing digital data). Perhaps more significantly, however, is how Cherish has changed — and is continuing to change — the collective understandings of the physical and geographic locations they have selected as sites of importance. In a manner that resonates with Karen Barad's notion of *agential realism*, this thesis has rethought and reconceptualised these heritage sites by attending not only to how they're continually measured and observed, but to how the knowledges produced through these site-specific engagements feed back into our understandings of them in their blended archaeological and ecological contexts.

Standing under the welcome tent that day at Dinas, observing these consequences as they played out before me, I realised I would not have been able to arrive at the conclusions I

had were it not for the organisation and execution of my project up to that point. This, of course, began with my research questions. In grounding my research around the central question of how archaeological knowledges and methods of digital visualisation came to be constituted, I had deliberately primed myself for the observation of a multi-sited practice that was defined by both its distribution and the mobility of its iterative outputs. In specifically targeting the derivation of Cherish data, its translation at secondary stages of post-production, and its eventual and iterative coherence as discrete objects with specific functions, I felt I had rendered myself amenable — as a researcher and observer — to the dynamic, multi-sited, and multi-valent ways Cherish data could be visualised and used. Furthermore, in structuring my inquiries around the notion of Cherish data as being trans-local, I had, after Latour's *circulating reference*, further opened my research up to the consideration of Cherish workflows across and between sites and contexts. I could trace the assembling of knowledge-producing practices as they alternately gathered either in the field or in the lab as part of the situational assemblages.

My ability to do this was, of course, both predicated on and elaborated by the relationships I had developed with the theoretical literatures I had reviewed ahead of my fieldwork and analysis. In assemblage theory I had derived the means to not only consider Cherish and its methodologies as dynamic socio-technical ensembles composed of modular components, but as the means through which the distinct configuration and co-functioning of these components would result in the emergence of contingent and situated knowledges. Through the work of Karen Barad, Donna Haraway, and Natasha Myers, I had further developed the conceptual tools necessary to understand how the positionality and situated enactment of Cherish protocol — situated within these assemblages — crucially shaped the production of both digital visual data and knowledges they carried. Finally, through my review of contemporary discourse on the ontologies of digital objects, I found the means to

understand how the derivation of discrete models and objects was relationally contingent on the formalising principles of both the Cherish database and the configuration of softwares and platforms used to render them as technical objects.

Finally, the empirical content my project has produced was crucially shaped by the field methodologies I chose to employ on my visits to Ireland and Wales. In deriving substantial portions of my data through 'walk-along'-style and observational interviews I sought to foreground the perspectives Cherish practitioners and their unique situated relationships to both the methodologies they enacted and the data they produced. In positioning myself as a participant-observer I sought to elaborate these perspectives by tracing the contours of Cherish methodologies not readily obvious to my respondents. As an exercise in bringing theory with me to the field, this method proved particularly helpful. In undertaking my own experiments with the same datasets I had observed being acquired and processed, I was further able to enrich my understanding of Cherish outputs: how they are derived, what they are "made of", and how they can be alternately visualised or made coherent. From a structural standpoint, then, the line of inquiry I had established from the outset, the theoretical materials I had used to frame my methodical approaches, and the enactment of these methods in the field enabled me both to trace the production of Cherish's digital visual outputs in a manner that elucidated the contingency and complexity of their attendant knowledges *and* anticipate consequences of how these knowledges might be applied.

As I observed Toby use the 3D print of Dinas Dinlle to facilitate interpretive learning scenarios for a curious public about to rove the excavation, I couldn't help but view this gypsum-printed facsimile as a unique condensation of all I had observed and processed up to that point. This model, I knew, began as UAV survey. Daniel, in the same manner I had seen him undertake at Nab Head — or as Robert had at Dunbeg Fort — had begun by assembling

a "site of acquisition". The assembling of these sites, this thesis has established, is a process defined by the production and fitting together of various spatial registers. Daniel, I knew, had approached Dinas with a preconceived notion of the model, or models, his survey would likely come to produce. Furthermore, I understood that these notions were shaped by both the definition of the boundaries and points of interest either he, or another Cherish investigator, had identified within the physical landscape *and* the prescribed limitations inherent to the technologies and tools he would use to conduct the survey. I also understood that the assemblage of this site of acquisition had been further predicated on the construction of referential spatial networks, which had been produced using highly accurate GNSS instruments and the subsequent distribution of what are known as control targets. Perhaps most significantly, however, was the degree to which the distribution of control targets and the derivation of abstracted spatial registers had ultimately served as the means through with the rendering of the visual data outputs would be made spatially relational and ultimately cohesive. The data Daniel had “captured” or “acquired” at Dinas Dinlle, then, was not some mimetic transfer of the landscape itself, but a densely intertwined series of coordinate-based and image-based datasets requiring unique and assembled spatial registers in order to hang together. As such, the correspondence between the data produced and the landscape it would model was mediated or filtered through a distinct assemblage of technology, expertise, and the production of abstracted or virtual spatial registers.

In order to render this data as cohesive digital objects, which could then serve as the schematic baseline from which a 3D object could be printed, this primary data underwent a series of nuanced translations via stages of processing and visualisation. As this data travelled from field to the office—or from the SD cards of the GNSS antennas and drone-mounted cameras to the desk-based servers and softwares—it was duplicated, disassembled, edited, and reconstituted. Part of what also occurred, then, was that the spatial registers initially

inscribed through the processes of acquisition were likewise dramatically reconfigured at these stages. Not only would the alignment of the initial images be rectified by distributing the registered coordinates for the control targets throughout the cloud, but the very cohesion of the resulting sparse clouds, dense clouds, and wireframe meshes was predicated on the synthesis of the initial coordinate-based and image-based datasets. The data at these stages (which, it should be mentioned technically become *new* data by virtue of this processing) were then further subjected to editorial processes of cloud cleaning and segmentation. Perhaps most significantly, given how the processual cohesion of these datasets was predicated on establishing a system of coordinate-based geo-locative relationality, the very production of discrete clouds and meshes directly resulted in the production of *new* spatialities. As such, the more the rendered outputs came to visually resemble the physical landscape of Dinas Dinlle the more they were increasingly defined by the reflexive configurations of their arrangement in these distinctly digital contexts rather than any correspondence to the physical spaces that had been photographed.

In order to be printed in gypsum, the data that Daniel had first "acquired" at Dinas Dinlle and then processed in Aberystwyth would need to be formalised as a digital object readable to whatever softwares and platforms would ultimately be used to print it. This process of formalisation actually began at the secondary stages, when the initial datasets acquired in the field were duplicated and loaded onto the databases the RCAHMW hosts on its servers. As these secondary stages of processing and visualisation were carried out, the iterative states of the resulting data were likewise saved within these same databases. Furthermore, because Cherish lacked the capacity to print the model themselves, certain sets of the iterative translations produced through the photogrammetric process would have to be selectively configured in distinct arrangements specific to the platforms they would eventually be sent. Their formalisation as objects, then, was predicated, firstly, on the way

they were indexed within a parent database, and, secondly, by the collective agencies of the softwares and platforms required to facilitate their printing. Crucially, these final stages of translation can be further defined by the degrees to which the data inputs are collectively reduced, decimated, and simplified: many such outputs contain nearly 95% less of their original geometric or structural complexity. Up until these the final stages of formalisation, these datasets and the objects they alternately compose might have been defined as epistemic things; that is, as distinct records of the knowledges Daniel had acquired during their production. Once formalised, however, they become — after Myers and Rheinberger — better described as technical objects. The configurational relationships so necessary to constituting their respective coherence at different stages now rendered unnecessary, these technical objects are now ready to break off from the assemblages that had formally defined them and enter into new contexts and applications.

By all accounts, the open community day at Dinas Dinlle was an enormous success. The turnout of attendees numbered in the hundreds (which exceeded my expectations for a relatively remote location in Northern Wales). There was tremendous enthusiasm about the status of the ongoing excavations. The finds in both trenches 1 and 2 were revealing massive structures of unprecedented size. As visitors congregated around the welcome tents both before and after their guided tours of the active dig, I could sense the extent to which the Cherish Project was actively reconfiguring a collective understanding of this threatened heritage landscape. After months of preliminary survey and analysis (which had been facilitated through the production and circulation of the digital objects generated through such efforts) the project had broken ground. In so doing, they had permanently altered the previous understanding of the site. What was once a landscape dotted with anthropogenic earthworks—with built or structural heritage only presumed to be under the earth—Dinas had now become an active site of investigation. Furthermore, given the contextual justification

for the excavation — i.e., the rapidly encroaching erosion on its western face — our understandings of Dinas Dinlle in past, present, and future contexts all became densely intertwined. Much of this also had to do with the printed model itself. This object, derived from numerous "epistemic things", was finding dynamic and meaningful application at the event as a distinct technical object which, much in the manner described by Natasha Myers and Hans Jörg Rheinberger, was now being "put to the task of determining other epistemic things" (Myers, 2016, pg. 79). Having carefully traced the production of such objects — from their initial derivation to their eventual cohesion — I had come to understand the unique fitting-together of assemblages that convened around each of the stages inherent to their production. Now reified as a tool of interpretive learning, I could sense the new assemblages gathering around it. Cherish was using this printed model — and, by extension, all of the procedures and methods that had made its rendering possible — to construct meaningful associations between their methodological approaches to monitoring and management and how the public might come to understand these threatened heritage spaces. Listening to visitors reflect on their own personal relationships to this space, on how they had observed its collapses — even walking the site myself, peering into partially excavated holes hinting at massive structures not 2 metres from a rapidly degrading cliff — I could feel the reality of this site changing. Not only is Dinas Dinlle — like all of the sites Cherish has selected for study — dynamic, temporary, rapidly disappearing, and rich in heritage, but it is perpetually reified and shaped by the nature of our engagements with it: digital, visual, or otherwise.

Glossary of Terms

Types of Survey

Photogrammetry: Photogrammetry is, in the simplest of terms, the extraction of three-dimensional data from visual two-dimensional inputs. The history of photogrammetry goes back to the advent of photography in the 19th century and has been expressed and explored through a great number of methods in the years since. In the early 2000s, for example, the Discovery Programme would conduct photogrammetric research of landscape surveys via the stereoscopic comparison of large-scale prints viewed through 3D glasses. Both the Discovery Programme and the Royal Commission on Ancient and Historical Monuments of Wales now primarily pursue photogrammetry through *Structure from Motion.*

Structure from Motion (SfM): A method of photogrammetry wherein sequences of two-dimensional images are used to approximate three-dimensional forms. The name, *structure from motion*, alludes to principle by which the human capacity for discerning three-dimensional forms is based in moving around them or observing an object move itself. In practice, Cherish teams use drones to photograph areas of interest from both orthogonal and oblique angles which, when taken collectively, comprise a comprehensive and exhaustive visual overview of the site or feature in question. Software such as Photoscan are commonly used to render these sequenced images as cohesive geometric forms.

Unmanned Aerial Vehicles (UAVs): A term used interchangeably by both the Discovery Programme and the RCAHMW to describe drones. There are several types of UAVs that have either been used, or are currently used, within Cherish to pursue UAV survey:

— ***fixed-wing UAVs*** refer to plane-like drones. These devices are primarily used to conduct LiDAR surveys of large-scale landscape targets, in that they are remarkably stable and can travel long distances for extended periods of time.

— ***copter UAVs*** refer to helicopter like drones, such as the DJI Phantom IV pro; the drone primarily used for the surveys observed and described within this thesis. Copter UAV's possess a dynamic range of motion and are easily piloted, enabling practitioners to alternately conduct pre-programmed flights to capture orthogonal imagery *and* manually piloted flights to capture oblique images. These devices are also easily fitted with a range of mountable digital cameras.

Laser Scanning: Laser scanners primarily operate to remotely sense their targets in one of three ways:

— ***time of flight*** scanners intermittently emit laser pulses while rotating from fixed positions. In a manner similar to sonar, the scanner calculates the time it takes for these emissions to be reflected in order to determine the distance and orientation between the scanner and the scanned surfaces. Laser scanner work observed for this thesis was done using time of flight scanners made by the Faro company.

— ***phase-based*** scanners work by emitting a consistent laser pulse and measuring the disturbance between emitted and reflected pulses (known as "backscatter") to determine the location and contours of scanned surfaces.

Both time of flight and phased based scanners produce register their readings as individual points with discrete locative coordinates and readings for colour. Collectively these points are exported as point clouds.

Phasing: A term used by field archaeologists to describe the process by which they interpret the chronological relationships between identified and documented features. In specificity, phasing describes when anthropogenic features were likely built and how they interact with features built at earlier or later stages in history.

Geo-physical Survey: As one of the final methods of survey before undertaking excavation, geo-physical survey provides the means for practitioner to search out and detect archaeological evidence not readily apparent on the surface. Geo-physical survey is commonly executed my assembling a grid of pathways on the surface of the area of interest. Here, using a cart mounted with a specific type of sensors, practitioners walk along the gridded patterns to produce comprehensive datasets of what is (potentially) under their feet. To date the Cherish Project has either conducted or commissioned two specific types of geo-physical survey at sites of interest:

— **Resistivity Survey**: This type of survey is conducted using an apparatus that emits electrical waves into the ground. This apparatus is designed to measure the resistivity of materials to these emissions, the returns of which can be visualised as vague shapes and forms.

— **Magnetometry Survey:** This method of survey measures the magnetic field of the ground being surveyed. Given the magnetic variance of materials such as stone, clay, etc., the returns from these surveys produce rough visualisation of the different magnetic fields surveyed.

Geolocative Referencing Terms

Global Positioning System/Global Navigation Satellite System (GPS/GNSS): Used interchangeably, GPS and GNSS refer to the means by which individual geo-locative coordinate readings are registered in the field. Commonly returned with readings for northings, eastings, and elevation, Cherish practitioners produce GPS/GNSS data by synching their GPS/GNSS antennas (the RCAHMW uses equipment manufactured by Leica, the Discovery Programme use Trimble equipment) with either *Virtual Reference Stations* or *Real Time Kinematic* networks.

Virtual Reference Station (VRS): In order to register accurate readings in remote locations, both the RCAHMW and Discovery Programme subscribe to Virtual Reference Station services. VRSs function as fixed locations capable of collating local satellite configurations adjacent (generally within 20km) to the field-sites being surveyed. The geo-locative data gathered in the field is than post-processed against the data provided by the VRS, thus refining geo-locative measurements to thresholds of accuracy within centimetres.

Real Time Kinematic network (RTK): In the event that a location being surveyed is too remote to access the closest VRS (as was often in the case at Welsh Cherish sites), practitioners construct Real Time Kinematic networks which, in principle, function as local VRSs. Using a mobile base station to collate readings from local satellites at the time of the survey, the constructed RTK is capable of making real time locative adjustments to

coordinate-based readings made by the roving antennas practitioners carry with them in the field.

Global Coordinate Systems (GCS) and Map Projections: Map projections ensure that GPS/GNSS coordinates can be visualised as cartographic products with minimal distortion. As two-dimensional renderings of three-dimensional spaces and surfaces, all maps contain some degree of distortion and warping based on these translations. Map projections work by specifically focusing on regional accuracy. As such, a map projection designed for Welsh coastline will be insufficient for charting coordinates taken in Ireland, and vice versa. All map projections are derived from Global Coordinate Systems, which are comprised of fixed coordinates distributed across the globe. The most recent GCS is the WGS84, or World Geodetic System 1984, a global datum produced in the 1980s but updated as recently as 2014.

Visualisation Terms

Key points and Tie points: During the photo alignment of stages of photogrammetry key points are shared 2D points located across the selection of images submitted to processing. Key points are selected on the basis of the size of the images submitted and the visual content of such images. Tie points, by contrast, are 3D point (derived from corresponding key points) which the software detects, computes, and plots within the digital workspace of the photogrammetry software. It is these tie points which compose both the sparse and dense point clouds of photogrammetry projects.

Raster-based analysis: Data can be visualised within a GIS in one of two ways: as vectors or as rasters. Vectors are strictly point and line based, where rasters uses cell-based imagery to represent location and position within a geo-referenced workspace. Given that any of the two-dimensional outputs produced from photogrammetry are exported as image files (such as .jpegs, .tiffs, or .pngs), any type of analysis — be it with ortho-mosaics or DEMs — is inherently raster-based.

Ortho-mosaics: Ortho-mosaics are two-dimensional images produced from three-dimensional renderings. Because they're produced through photogrammetry, the objective is to have close to no radial distortion anywhere within the images, meaning geo-locative data can be populated across the entire image with remarkable accuracy. Often Ortho-mosaics are analysed using GIS software like ArcMap or QGIS.

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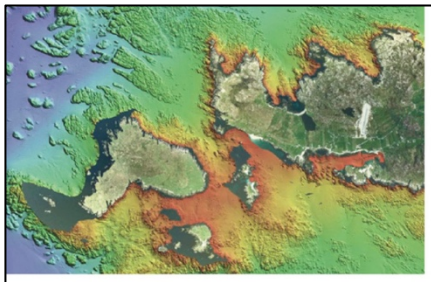
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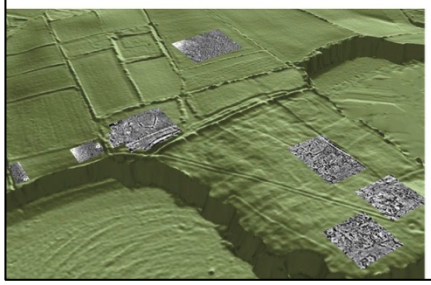
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Appendix I: The Cherish Project Executive Summary (2016)


EU Funds: Ireland Wales Co-operation Programme 2014-2020
CHERISH
Newid Hinsawdd a Threftadaeth yr Arfordir
Climate Change and Coastal Heritage
Athrú Aeráide agus Oidhreacht Chultúrtha
"Understanding climate, risk and the remote heritage of the Irish Sea Zone"
4 Partners
8 Ultimate Changes
across
during
9 Initiatives
5 Year Operation (2017-2021)
Direct Delivery by Beneficiaries
Overall operation value:
€5,183,913
Total ERDF grant:
€4,144,836
Royal Commission on the Ancient and Historical Monuments of Wales,
Geological Survey, Ireland,
The Discovery Programme, Ireland,
DGES Aberystwyth University
EXECUTIVE SUMMARY
Aligned with Priority Axis 2:
Adaptation of the Irish Sea and Coastal Communities to Climate Change
Specific Objective 2:
To increase capacity and knowledge of climate change adaptation for the Irish Sea and coastal communities
Comisiwn Brenhinol Henebion Cymru
Royal Commission on the Ancient and Historical Monuments of Wales
Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann
The Discovery Programme
Centre for Archaeology and Innovation Ireland
Prifysgol Aberystwyth University
Cronfa Datblygu Rhanbarthol Ewrop
European Regional Development Fund
1







CHERISH: Climate Change and Coastal Heritage

CHERISH will increase cross-border knowledge and understanding of the impacts (past, present and near-future) of climate change, storminess and extreme weather events on the cultural heritage of reefs, islands and headlands of the Irish Sea. The operation will target data and management knowledge gaps, employing innovative techniques to discover, assess, map and monitor heritage assets on land and beneath the sea. CHERISH will raise awareness about the impacts of climate change on heritage, train the citizen scientist and widely disseminate the results. It will develop best practice and guidance, making recommendations for future adaptation.

The reefs, islands and headlands of the Irish Sea have a rich cultural heritage. These are iconic locations in the coastal and maritime culture of both nations, and home to a number of designated heritage assets. Yet they remain largely unexplored, inadequately mapped and their environmental context poorly understood. These remote, exposed environments are at constant risk through exposure to extreme weather and storms, which are predicted to increase in intensity and frequency due to climate change. CHERISH will map past environments and will model predicted changes over the next 100 years to form the basis for management recommendations for future climate change adaptation. Selected heritage assets expected to be impacted by climate change in the next 100 years – on land and under the sea – will be surveyed, sampled and dated within the study areas.

2

CHERISH will implement a cross-disciplinary, cross-border Survey Team linking land and sea that brings together partners who are leading specialists in a variety of fields – climate change, hydrography, geology, archaeology, built and maritime heritage, remote sensing, environmental science, storminess and scientific dating.

CHERISH Delivery 2.5



The CHERISH Legacy: Adaptation Tools for the Future

Informing Government Strategies	• CHERISH will contribute directly to Government Strategies on Climate Change, including the overarching objectives and priorities of the Welsh Historic Environment Climate Change Sectoral Adaptation Plan (SAP), Ireland's EPA Research Strategy 2014-2020 Climate - Water - Sustainability, and the recommendations of the 2009 Heritage Council and Fáilte Ireland report on Climate Change, Heritage and Tourism.
Informing Decision Making	• Open access data generated by CHERISH will enable improved decision-making regarding the historic environment and climate change adaptation at all levels, from local communities through to Government. • Open access data will inform Strategic Assessments of Coastal Flooding and Erosion Extents in Ireland, and Integrated Coastal Zone Assessments and Shoreline Management Plans in Wales.
Future Change and Adaptation	• CHERISH will provide new data to address threats and opportunities presented by The Climate Change Risk Assessment (CCRA) for Wales (2017). • It is anticipated that palaeoenvironmental and historical data produced by CHERISH will contribute to development of the next CCRA (2022). • Synthesis of historical and palaeoenvironmental storminess records across the region will identify variability in storm frequency and intensity and their impacts over millennia, providing valuable data for projections of future change.
Baseline Data and Guidance for Future Monitoring	• CHERISH will provide the first 3D baseline fixed survey points and data for selected heritage assets specifically aimed at future monitoring of climate change in the Irish Sea zone. • CHERISH will develop joint methodology, best practice and practical guidance for evaluating the risk, sensitivity and adaptive capacity of the coastal and marine historic environment.
Informing Better Management	• Following the principles of Natural Resource Management we will ensure CHERISH works in an integrated way with landowners, statutory bodies and other Ireland-Wales operations involved in the management of, and strategies for, the Irish Sea zone. • CHERISH will provide management data and plans for study areas, highlighting sites at risk from future loss.
Building Knowledge and Capacity	• CHERISH will provide mechanisms (guidance, workshops and seminars, etc.) and platforms (shared web portal, open access data, Historic Environment Records and a sustainable archive to European standards) to disseminate existing and new research. • Initiatives to train citizen scientists through CHERISH will leave a legacy of increased awareness and transferable skills among coastal communities. • The CHERISH methodology could usefully be widened to other islands, reefs and remote coastal landscapes of the Atlantic area where climate change threatens cultural heritage and future landscape management.

4

A Stimulus for Jobs and Growth

CHERISH will provide new coastal heritage information and innovative products that will be a stimulus for encouraging tourism and growth in the blue economy, as well as raising knowledge, skills and awareness. This links closely with the overall strategic ambitions of the Irish Action Plan for Jobs. Likewise, for Wales, the operation will contribute to other investment programmes, backbone and core activities as highlighted in the Economic Prioritisation Framework, for example the theme of 'tourism, recreation and leisure'. There will be a positive impact on the well-being of those who live in, work in and visit the Programme area. There is a clear association between heritage and the historic environment and several factors of well-being including quality of life, environmental life, personal development, and sense of place and ownership of local heritage. (CHERISH Strategic Fit 1.1)

Working in Partnership for Stronger Outcomes

CHERISH is a cross-border action between leading specialists, providing a cross-sectoral partnership of statutory bodies, HEI and Research Institutes. The CHERISH Advisory Committee will provide expert guidance and oversight. We will work with our 18 agreed stakeholders in both nations, including The National Trust and The Heritage Council, local authorities, universities and charitable trusts, to build on their own Climate Change policies and strategies through the new opportunities offered by CHERISH.

CHERISH will deliver the following outputs against Main Priority Axis 2 Output Indicators (SO2)*

Number of research institutions participating in cross-border, transnational or interregional research operations (Target Value 10):

› CHERISH will provide: 2 (20%)

New awareness raising initiatives targeting coastal communities (Target Value 60):

› CHERISH will provide: 9 (15%)

Organisations cooperating in enhancing the marine and coastal environmen (Target Value 24):

› CHERISH will provide: 4 (16.6%)

*subject to confirmation of Result Indicator units and targets by WEFO RME Team

5



6 CHERISH Actions

All beneficiaries will collaborate to deliver a range of activities within the following six actions:

Action 1: Mobilisation and Planning

To ensure a smooth running operation and the capacity to deliver the objective.

Action 2: Desk Based Intervention

To collate current knowledge, develop monitoring systems and enhance historic environment datasets.

Action 3: Field Intervention

To gather new knowledge and undertake monitoring.

Action 4: Citizen Science and Dissemination

To engage and train coastal communities, share knowledge and raise awareness.

Action 5: Legacy

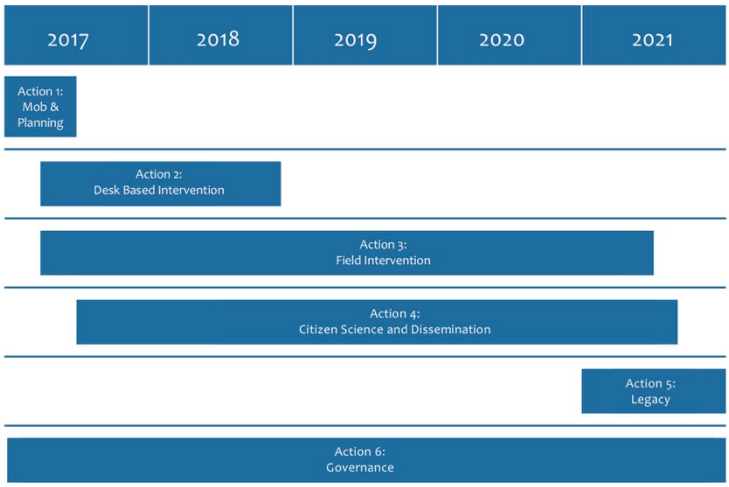
The creation of a sustainable resource, free data, management plans and best practice guidance.

Action 6: Governance

To engage with experts and managers from the field who will help to guide the operation and ensure delivery of the Objective.

6

6 CHERISH Actions: Timetable for Delivery



CHERISH Operation: Key Barriers and Risks

The Operation is informed by a full Risk Register combining Operational, Financial and Partner-specific risks, for which mitigation strategies are provided. Examples of key high-level barriers and risks include: potential withdrawal of a key partner (OP1), the continuing impact of EU Transition on the funding for CHERISH (OP5), future budget cuts among partner organisations could impact on match-funding levels (OP3), the potential for specialist staff leaving their posts early (OP7 (AB1, RC2, DP5 & GI3)) or potential issues around access to remote or rural CHERISH study sites (OP9).



This is an unparalleled opportunity for both nations to gather shared data and new cultural heritage information across the Programme area.

CHERISH Strategic Fit 1.1



8

9 Joint-nation CHERISH Initiatives (CI) will be delivered against the investment, fulfilling:

Specific Objective: SO2 To increase capacity and knowledge of climate change adaptation for the Irish Sea and coastal communities.
Outputs: 9 new awareness raising initiatives targeting coastal communities.

CI-1 CHERISH survey teams developing joint best-practice guidance

Integrated joint-nation teams deployed to survey and record heritage sites threatened by climate change in targeted coastal communities, using the latest innovative technologies and remote sensing techniques.

CI-2 CHERISH permanent network of 'local change' fixed survey markers and indicator wrecks

A key legacy of the operation, CHERISH will provide the first 3D baseline fixed survey points and data for selected heritage assets specifically aimed at future monitoring of climate change.

CI-3 CHERISH reefs, islands and headlands enhanced historic environment data inventory

An enhanced and updated national historic environment dataset, helping to inform priority lists for statutory designation.

CI-4 CHERISH reefs, islands and headlands enhanced palaeoenvironmental data Inventory

Multi-proxy palaeoenvironmental data within a robust chronological framework, developed from selected locations to reconstruct past environments and inform future adaptation strategies.

CI-5 CHERISH 3D reefs, islands and headlands: Seamless onshore/offshore 3D models

A number of innovative digital 'real maps' derived from LiDAR and photogrammetry, will provide 3D data geomatic data for planning and management.

CI-6 Training the citizen scientist

Engaging workshops, seminars and outreach events to raise awareness and train the citizen scientist in survey and recording, heritage at risk, climate change and storminess impacts.

CI-7 CHERISH climate change community excavations on heritage assets at risk

Community excavations will be run during CHERISH to train citizen scientists in local communities to record heritage sites at risk.

CI-8 CHERISH open access shared web portal

A key tool of CHERISH for information delivery and awareness-raising and an important legacy of the operation for future adaptation strategies.

CI-9 CHERISH landowner management plans for adaptation planning

Detailed management plans and GIS datasets for reefs, islands and headlands under study showing cultural heritage assets and climate change threats.



8 Ultimate Changes will be delivered by CHERISH (CHERISH Delivery 2.1a):

1. A stimulus for encouraging local tourism and growth in the blue economy.
2. Improved evidence base for statutory protection, decision-making and adaptation strategies.
3. Increased knowledge and awareness of heritage assets on the previously understudied and remote reefs, islands and headlands across the Irish sea.
4. New, detailed, multi-proxy palaeoenvironmental records from selected locations following an initial survey of existing data and assessment of potential sites.
5. Provision of open-access, accurate and high resolution baseline geomatic data.
6. New joint-nation best practice guidance.
7. Innovative data capture, modelling and visualisation products.
8. Identification of 'at risk' cultural heritage sites.

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Operation Strategy: Management and Delivery of CHERISH

Governance

CHERISH Advisory Committee

- Statutory agencies and governmental policy.
- Climate change, coastal, maritime and island expertise.
- Academic peer review.

Direct Delivery by Beneficiaries

Royal Commission Wales (LEAD)

- Lead administration
- Archaeological investigation & intervention
- Aerial reconnaissance
- LiDAR
- Baseline surveys
- Community engagement & innovation
- Data enhancement & archiving

Geological Survey, Ireland

- Marine bathymetry
- 3D seabed mapping
- Data collection & analysis
- Visualisation of big data
- Data capture
- Research & Development

Discovery Programme Ireland

- Archaeological investigation & innovation
- Baseline surveys
- Drone/UAV data capture
- Geophysical survey
- Photogrammetry
- Application of remote sensing and geospatial technology to heritage

DGES Aberystwyth University

- Paleoenvironmental & climate change expertise
- Historical climate research
- Advanced instrumentation for palaeoenvironmental data collection
- Analysis & dating

CHERISH Survey Team

Integrated joint-nation collaborative approach to archaeological, marine and palaeoenvironmental investigation and survey, field intervention, training, dissemination and citizen science.

Staffing

The operation will create 7 FTE posts: Project and Finance Manager and a Coastal Archaeological Investigator (RCAHMW), a Geologist and a Senior Marine Geophysicist (GSI), a Lead Project Archaeologist and a Project Archaeologist (DP) and a Post-Doctoral Research Assistant (AU). These posts will be supplemented through the in-kind contribution of existing specialist staff at each of the partner organisations, as detailed in the CHERISH Budget.

Stakeholders & Private Sector

Stakeholder Engagement

- Curatorial and regulatory oversight
- Landowner liaison
- Training and collaboration
- Knowledge sharing
- Outreach events
- Citizen science

Private Sector Procurement

- Aircraft and boat hire
- Safety training and remote access
- LiDAR acquisition
- Radiocarbon dating
- Indicator wreck condition monitoring
- Printing/manufacture
- Film making/publicity

Delivery

CHERISH Delivery Plan Model: Six Actions: 2017-2021

9 CHERISH Initiatives / 8 Ultimate Changes

Output Indicators and Targets For Priority: Axis 2, Specific Objective 2

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Appendix II: The Discovery Programme UAV Processing Workflow

The Discovery Programme
Centre for Archaeology and Innovation Ireland

AGISOFT PHOTOSCAN – UAV PROCESSING WORKFLOW

Document Reference and Version No	AGISOFT UAV WORKFLOW Version 0.8
Purpose	The purpose of this document is to detail the workflow for processing data captured from a UAV in Agisoft Photoscan
Creation Date	October 2018
Date of Next Review	October 2019
Revision History	New Document Agisoft Photoscan Professional Edition. Version 1.4.4 build 6848 (64 bit)
Document Author	Technology Manager

OVERALL WORKFLOW

1. Setup Project
2. Import Images & Check Image Quality
3. Transform photographs from WG84 to national coordinate system
4. Align photographs which builds a Sparse point cloud (tie points).
3. Optimize Sparse point cloud and alignment.
4. Build a Dense point cloud, may need manual cleaning.
5. Build a polygon Mesh.
6. Build a texture for the Mesh

DETAILED WORKFLOW

1 SETUP PROJECT

Select New Photoscan project

FILE > NEW

Save Photoscan Project with appropriate Name and Stage Description

FILE > SAVE AS

Use the format for file name

DATE_SITENAME_PROCESS_STAGE.psx

e.g. 20181016_CARROWKEEL_START.psx

REFENCE TAB
SETTING
CORD setting
Mker Accracy 0.01m

2 IMPORT PHOTOGRAPHS

Photos can be added by selecting them and dragging them into the Photoscan workspace or through the workflow menu within Photoscan.

WORKFLOW > ADD PHOTOS

Select Images > OPEN

Checking the quality of the photographs being used- ideally the photos should have good overlapping coverage of the object or area being modelled with good consistent lighting. Distorted, out of focus or noisy images should be disabled. Manually remove images that are obvious 'outliers' (e.g., images that have been taken before take-off etc.)

Checking the quality of the photographs being used- ideally the photos should have good overlapping coverage of the object or area being modelled with good consistent lighting. Distorted, out of focus or noisy images should be disabled

WORKSPACE TAB
EXPAND CAMERAS > RIGHT CLICK IMAGES> ESTIMATE IMAGE QUALITY
SELECT = ALL CAMERAS

This will give each image a quality number value, generally speaking, a decent photo should have a **rating higher than 0.7**.

Save Project > DATE_SITENAME _1_PHOTOS.psx

3 CONVERT IMAGE COORDINATES & CORRECT UAV IMAGE ALTITUDE

Convert GPS coordinates of your geotagged images (WGS84) to match the coordinate system of your ground control points (GCPs) which will be imported later.

REFERENCE > CONVET >IRENET95 / Irish Transverse Mercator Cameras ticked

Note that the altitude information stored in the EXIF data of imagery acquired by DJI drones is the relative altitude from the point of take-off and not the absolute/real world altitude it therefore needs adjusting by running a Python Script (https://github.com/agisoft-llc/photoscan-scripts/blob/master/src/add_altitude_to_reference.py)

TOOLS > RUN SCRIPT > SELECT FILE = add_altitude_to_reference.py
From CUSTOM MENU > ADD REFERENCE ALTITUDE
Please specify the height in meters to be added: 120 (normal setting)

SAVE PROJECT > **DATE_SITENAME _2_ITM.psx**

4 ALIGN PHOTOGRAPHS

WORKFLOW > ALIGN PHOTOS
General Settings
- QUALITY = HIGH
- GENERIC PESCISION = YES
- REFERENCE PRECISION = YES

Advanced Settings
- KEY POINT LIMIT = 900,000
- TIE POINT LIMIT = 0
- ADAPTIVE CAMERA MODEL FITTING = YES

Save Project > **DATE_SITENAME_3_ALIGNED.psx**

5 GROUND CONTROL POINTS

Select image with Ground marker present
Move image so the GCP marker is present in the centre and zoom until you can see a detailed view
Right click on marker in image > ADD MARKER
Right Click on Marker in Reference Window > RENAME MARKER
Type in relevant GCP Name e.g. T112

Import GCP data
Coordinate system >
- DELIMITER = COMMA
- Select columns for LABEL< EASTING, NORTHING, ALTITUDE

Check in table below to make sure correct fields are selected
Error large
Uncheck all cameras
Uncheck two markers from optimisation – use as control point to evaluate accuracy

OPTIMIZE CAMERAS (all options except FIT P4)
DUPLICATE CHUNK
Rename Original CHUNK = CHUNK_1 _ALIGNED
Disable CHUNK 1 _ALIGNED
Rename Copy CHUNK = CHUNK_2 _DENSE_CLOUD

Save Project > **DATE_SITENAME_4_GCP.psx**

6 CLEAN SPARE POINT CLOUD

Reconstruction Uncertainty - removes tie points which have a low probability of being in the right place

MODEL > GRADUAL SELECTION > RECONSTRUCTION UNCERTAINTY
LEVEL = 12
DELETE SELECTED POINTS
OPTIMIZE CAMERAS (all options except FIT P4)

Reprojection Error- is a measure of accuracy of the points, measured in pixels

MODEL > GRADUAL SELECTION > REPROJECTION ERROR
LEVEL = 0.5 OR LESS
DELETE SELECTED POINTS
OPTIMIZE CAMERAS (all options except FIT P4)

Projection Accuracy - filters out points which have projections that are relatively poorly localised due to their bigger size.

MODEL > GRADUAL SELECTION > PROJECTION ACCURACY
LEVEL = 10
DELETE SELECTED POINTS
OPTIMIZE CAMERAS (all options except FIT P4)

REPEAT Reconstruction Uncertainty - removes tie points which have a low probability of being in the right place

MODEL > GRADUAL SELECTION > RECONSTRUCTION UNCERTAINTY
LEVEL = 12
DELETE SELECTED POINTS
OPTIMIZE CAMERAS (all options except FIT P4)

Save Project > **DATE_SITENAME_5_OPTIMIZED.psx**

7 BUILD DENSE POINT CLOUD

WORKFLOW>BUILD DENSE POINT CLOUD
QUALITY = HIGH
DEPTH FILTERING = AGGRESSIVE
Save Project > **DATE_SITENAME_6_DENSE_CLOUD.psx**
Remember to save the project before viewing the dense cloud results

1 Build mesh (not needed if you just want a DEM and/or orthophotograph)

2 Build texture (not needed if you just want a DEM and/or orthophotograph)

8 BUILD DEM

WORKFLOW > BUILD DEM
Projection> IRENET95/Irish Transverse Mercator

Parameters > Dense Cloud
Interpolation > Enabled
Point Class > All
Default region & resolution settings

Save Project > **DATE_SITENAME_7_DEM.psx**

9 BUILD ORTHOMOSAIC

WORKFLOW > BUILD OTHOMOSAIC
PARAMETERS
Surface = DEM
Blending Mode = Mosaic
Enable Hole Filling = No

Save Project > **DATE_SITENAME_8_ORTHOIMAGE.psx**

EXPORT OTHO

Pixel size 0.025

Split into blocks 4000 x 4000 100m tiles
Setup boundaries with 100m edges
e.g. 574900 – 575600 - X

4 Further Information

If you have queries in relation to this document or any requested updates, please contact:

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Appendix III: Nvivo Codebook

Initial Coding

Nodes\\Revised Codes

Name	Description	Files	References
Assemblage Codes		4	5
Circulation and Transference	Content coded at this node concerns the movement or transfer of components (IE, practitioners, softwares, instruments, and data) ‘assembled’ across and between ‘sites’.	39	208
Disassembly and Reconstitution	Content coded here pertains to arrangements of components both cohering and being taken apart across sites. Part of what this code aims to establish is the degree to which arrangements across site are comparable.	35	140
Invarience and Singularities	Content coded here concerns aspects or elements of perceived assemblages that remain constant as they both circulate and are alternately disassembled or reconstituted.	12	25
Patterns	Content coded at this node concerns the degree to which the circulation and/or arrangement/re-arrangement of components across or between sites can become standardised or replicated.	17	52
Digitality Codes		1	1
Application	Content coded here pertains to the ways in which both data and/or digital objects are ‘used’ or applied.	28	134
Archives	Content coded at this node concerns the storage and preservation of Cherish data and Cherish data objects, specifically as they might relate to one another in the context of a overall deliverable for the project.	16	50
Cohesion	Content coded here addresses the ways in which Cherish datasets are seen or discussed as hanging together and condensing into discrete “data objects”.	32	236
Mass		19	69

Name	Description	Files	References
Metadata	Content coded here concerns all discussions and observations concerning the metadata schemes used (or, not used, as could be the case) to annotate Cherish data as it is generated.	24	93
Processes	Content coded here pertains to the various ways in which data is submitted to processes of rendering, registration, refinement, and so on. Whats particularly at stake here are the instances where Cherish practitioners submit data to engines or functions within software that are often automated and, occasionally, black-boxed.	31	315
Registration	Registration, in the context of Cherish data, refers to the means by which numerous datasets (derived from scans/photogrammetry, etc.) are rendered as compatible and relatable to one another, specifically as they cohere into discrete models.	29	125
Resolution	Content coded here addresses the various degrees of accuracy either targeted or achieved within Cherish datasets and, by extension, the protocols and mediating factors that determine such metrics.	23	44
Other	Content coded here seeks to highlight any and all striking data that does not necessarily fit neatly into the categories outlined thus far.	17	32
Practice and Performance		0	0
Collaboration		15	42
Interpretation	Content coded here seeks to establish something of the correspondence—either observed or discussed—between where and when site interpretation takes place and how such interpretation relates to concerns of location, orientation, distance, etc.	24	127
Orientation	Content coded here concerns: 1.) where and how Cherish practitioners are physically situated in relation both to the landscapes they are surveying and the instruments/components necessary do so. 2.) How Cherish practitioners are or become oriented with respect to digital landscapes in data processing or analysis contexts.	28	95
Performance	Content coded here concerns how practitioners execute various tasks, and how or whether such execution is reflective or habituated of standardised methods of enactment.	42	358
Position	Position is a loaded concept/word in the context of the Cherish Project. Given the degree to which GPS/GNSS is pervasively used in the acquisition, registration, and	35	166

Name	Description	Files	References
	processing of all digital/visual data, this node seeks to organise discussions of position in several contexts; as it pertains to the position of a practitioner in relation to physical landscape as well as the translation of such positions in digital contexts, for example.		
Seeing and visualisation	Content coded here concerns the various ways that which is (or is not) visible to practitioners—or is rendered visible via the projection of vision through an apparatus like a drone or scanner—comes to factor in the production of digital heritage landscapes across all perceived sites.	33	163
Strain and Demand	Content coded here concerns the physical stresses or demands placed on physical bodies of Cherish practitioners. This could pertain to the simple transportation of equipment to or from investigation sites, or to the demands drone flights place on practitioners with impaired vision, for example.	27	61
Sites and Situation Codes		1	1
Agency	Content coded here concerns the degree to which the composition of a site or the circumstances of a 'situation' are driven by a task/goal-based decision making and the execution of planned observations or measurements; IE how the circumstances of a site are organised around the enactment of certain objectives.	38	188
Arrangement and Composition	Content coded here addresses the manner in which 'sites' and situations can be described or conceived by virtue of their compositional elements.	41	298
Distance	Content coded here concerns the degree to which factors of distance determine the arrangement of components assembled across or between sites and the means by which such concerns are negotiated or come to matter to the execution of given tasks.	22	76
Inclusions and exclusions	Content coded here pertains to what comes to count, and what doesn't, in the composition of a given site or situation, paying particular mind to the degree to which certain choices and circumstances mean making compromises or exclusions.	34	161
Interfaces	Content coded here seeks to establish or highlight the specific points of interchange between and across components; IE where, when, and how subjective engagement/ observation is pursued via instruments, screens, or tools.	36	197
Interventions and engagements	Content coded here concerns the material nature of documenting an observation or	39	325

Name	Description	Files	References
	performing a given task; IE the enactment of a measurement, the registration of location, the initiation of a photograph.		