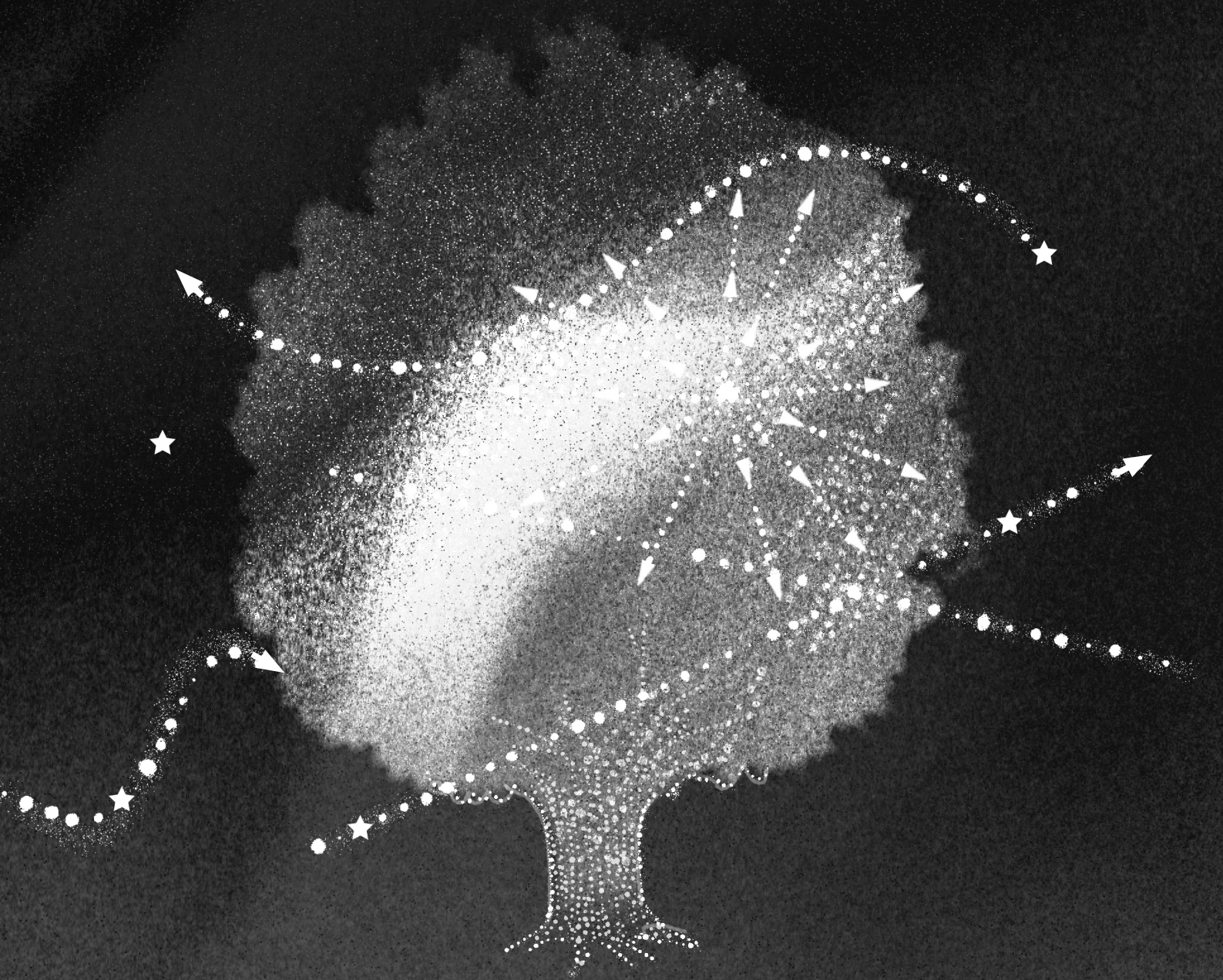


WHEN THE FOREST IS A CLOUD:

Understanding 'Lidar' technology
and the reanalysis of the Lidar 'point cloud'

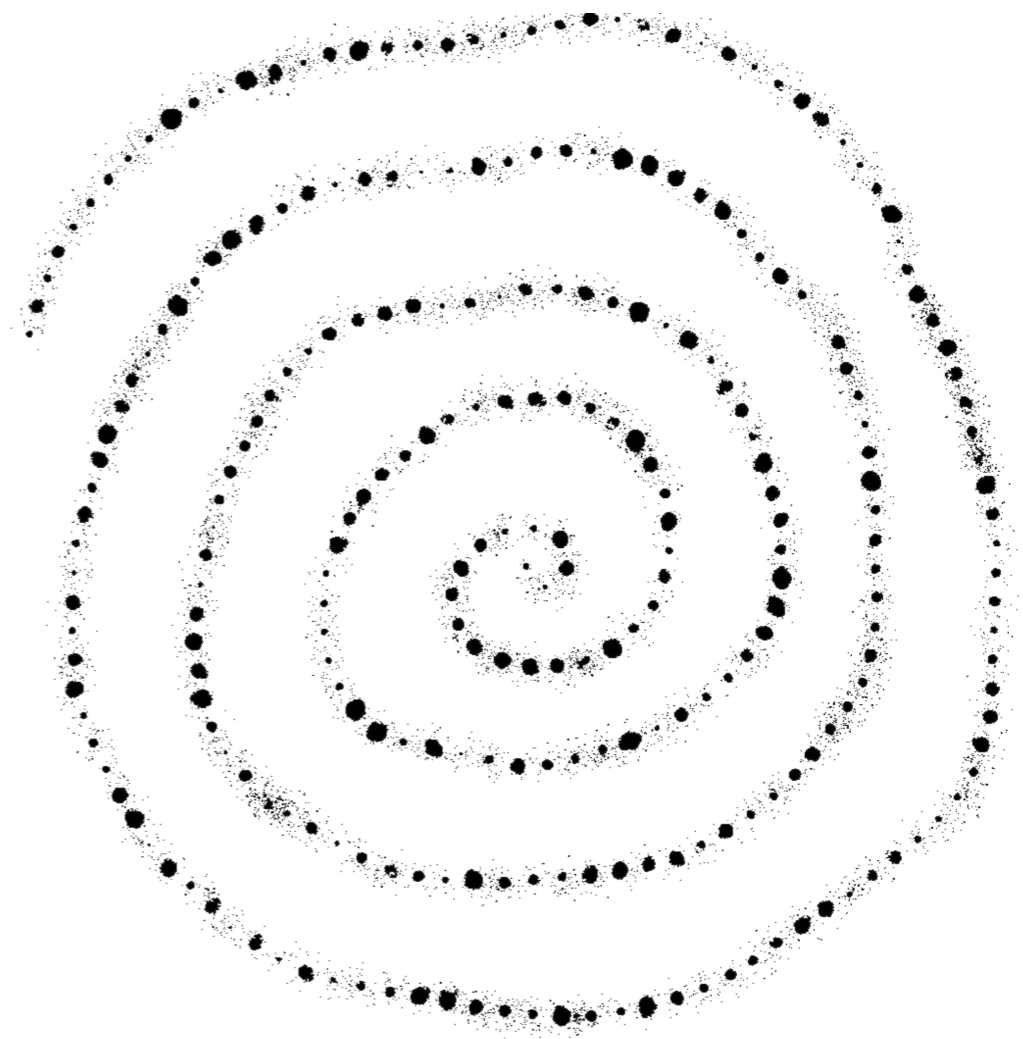


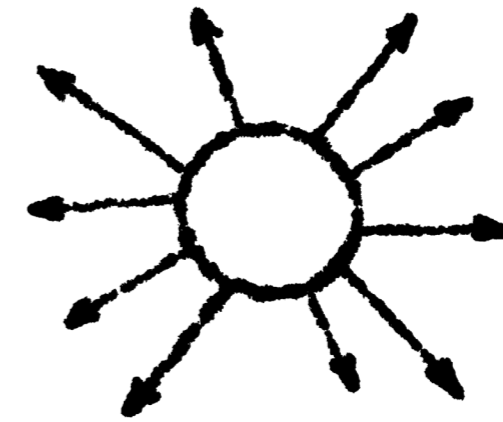
WHEN THE FOREST IS A CLOUD:

**Understanding 'Lidar' technology and the reanalysis
of the Lidar 'point cloud'**

The design and production of this pamphlet were made possible through funding from the UK Arts and Humanities Research Council, provided as part of a CHASE doctoral studentship held by Goldsmiths Politics Doctoral researcher Emily Gresham Beamer. The pamphlet design and illustration were created by Emily Cox.

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1. Aerial Lidar (Light Detection and Ranging)

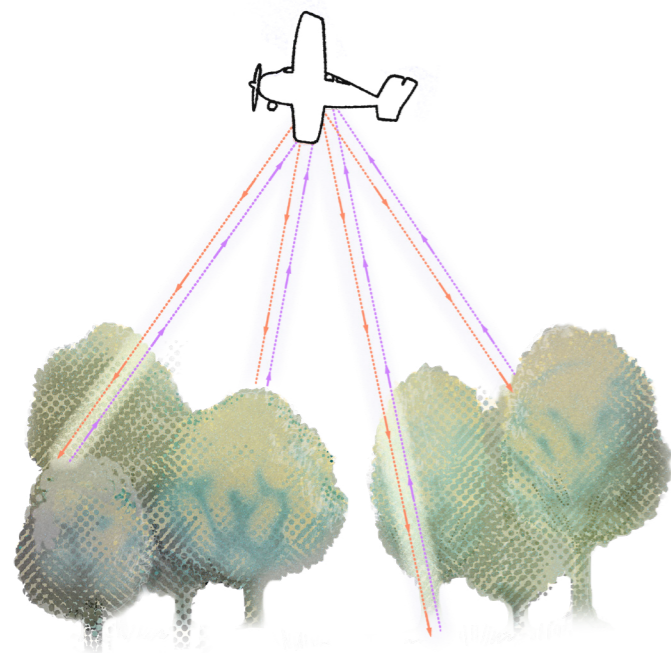
attached to drones, planes, and in some cases, satellites. When Lidar systems are attached to aerial vehicles above a landscape, they can create a three-dimensional image of it

also trace roads, rivers, footpaths, and man-made structures not visible from aerial photographs.

This pamphlet explains:

- ◆ How a Lidar system works
- ◆ How a discrete Lidar point cloud is composed
- ◆ Different ways Lidar point clouds are presently analysed
- ◆ Potential challenges to community autonomy that can arise when a Lidar point cloud is analysed post-survey
- ◆ Questions to ask if a Lidar survey is proposed
- ◆ 'Data Sovereignty' over the point cloud, and potential paths towards community point cloud reclamation and archiving

2. How does lidar work?



Light Detection and Ranging, or 'Lidar', is the practice of sending pulses of light towards a remote of this light pulse upwards once it hits a surface. Lidar systems can record the time each light pulse has taken to return to the aerial Lidar system's light sensor. The time it takes for each light pulse to return to the sensor is then used to calculate the distance between the Lidar system and the surface the pulsed light is returning from

alongside a measurement of the amount, or, **intensity** of the light energy

When Aerial Lidar systems operate above landscapes, landscape surfaces, by a Lidar system from the air above, without entering an area on foot.

come from the leaves and branches of a tree, the ground of the earth, buildings or small structures, and under-canopy landscape features such as crevasses and caves. While very dense tree canopies may hinder ground

underneath tree canopy.

3. The point cloud

A highly detailed model of an area can are collected, and then arranged in three-dimensions based on these time-based calculations of distance. Collected dimensional representation of landscape, known as a 'point cloud', as each as a 'point' in space.

These light pulses are fast. Modern Lidar systems can pulse light tens of

thousands to over a million pulses per second depending on the system. When arranged together into a point cloud, a highly detailed representation of landscape can then be both represented and **remotely interacted with**.

Again, the three-dimensionality of the point cloud is possible to calculate this 'distance' based on and return to the Lidar system after it has been pulsed downward. The sensor records both

position and the intensity the surface. The light

offer information about the character of the surface from

Further analysis can classify each point by surface-type.

vegetation type, structures, ground terrain, and water bodies.

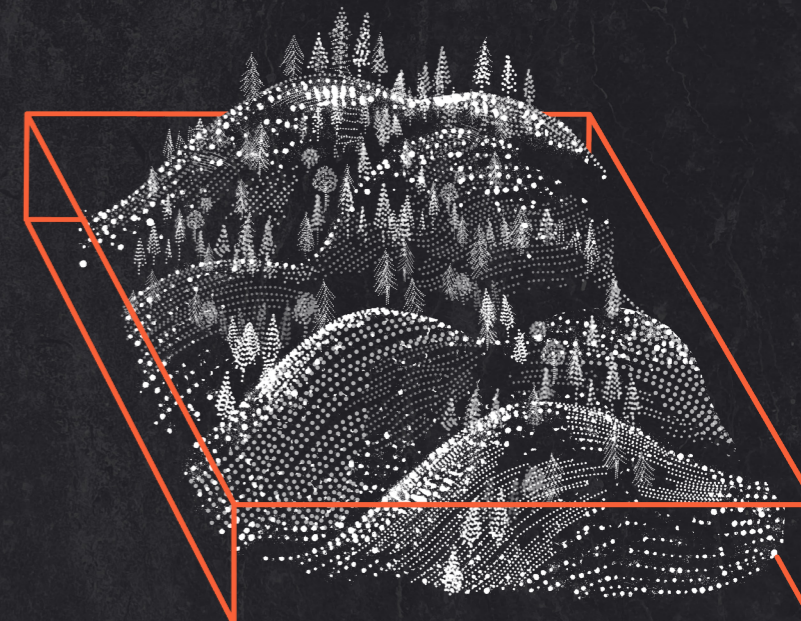
Crucially, these three-dimensional point clouds can

from **spaces previously sheltered from aerial images by the canopy of trees**. The Lidar system's pulsed light can cascade downward as

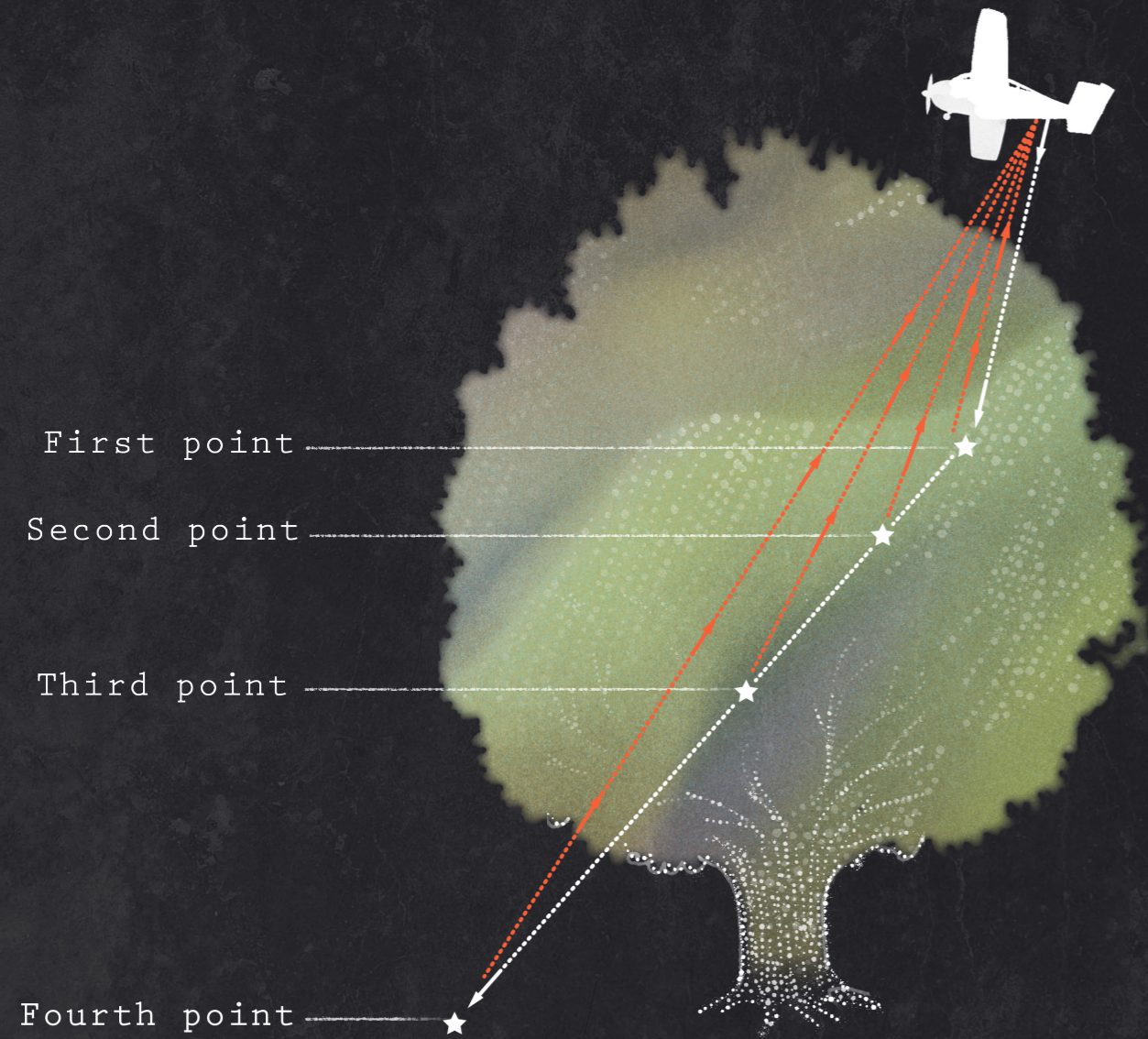
surfaces. Light can then reach *through* forest canopy and

Returns are ordered by the time taken

highest surface, while later returns may represent lower vegetation or the ground.

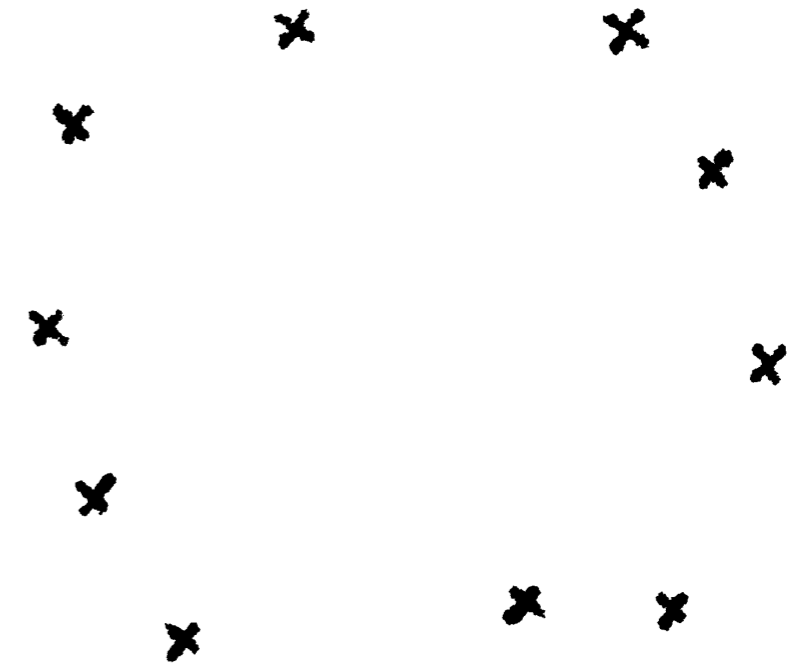


The shape of terrain, the mark of a trail, areas cleared of underbrush, and even archaeological features below forest canopy can now appear in virtual representation in the point

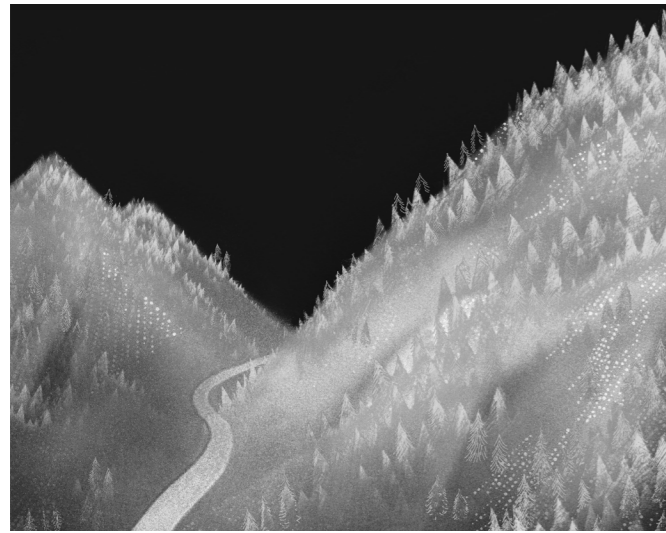


4. What can be reflected in a Lidar point cloud?*

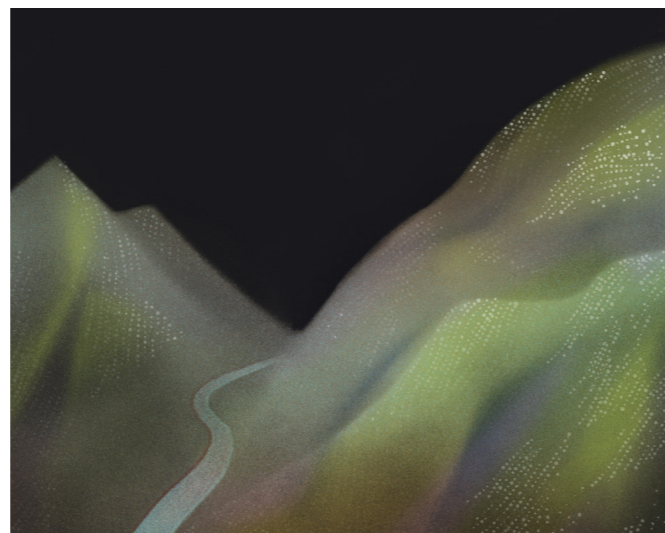
- ◆ Erosion, landslides,
- ◆ Roads, trails, footpaths
- ◆ Buildings and small structures
- ◆ Areas that have been cleared within a forest
- ◆ forest structure and canopy characteristics
- ◆ a forest area's canopy volume
- ◆ Individual features of material culture



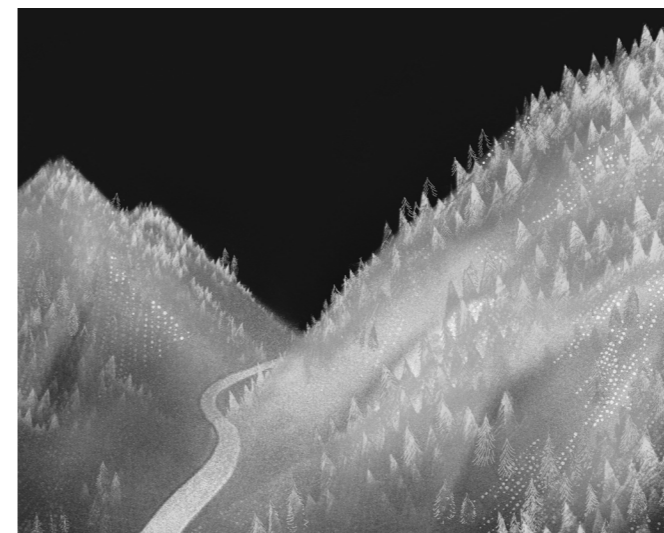
5. Points of reflection in a point cloud may be separated according to the object, surface type, and height where they reflected.



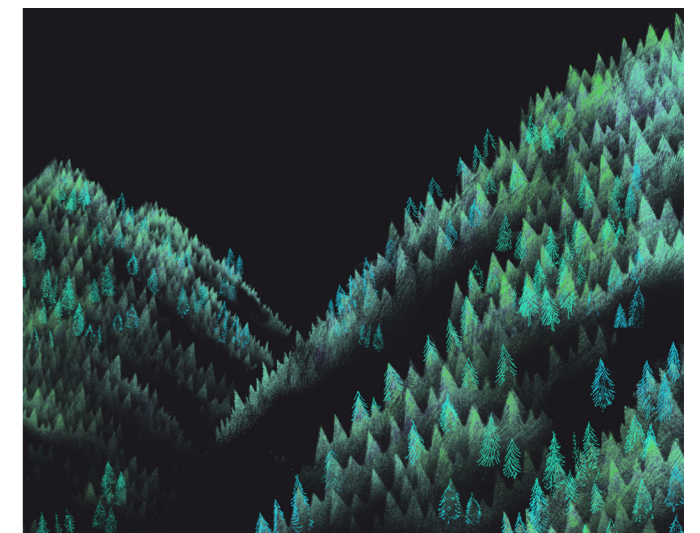
point cloud



DTM



point cloud



CHM

Digital Terrain Model (DTM):

This model represents only those the ground. These models exclude all vegetation and structures. They are often used for archaeological prospecting and mining explorations.

Canopy Height Model (CHM):

This model represents only points represents the height of the forest canopy. These models are often used alongside ecological information to estimate biomass from a particular forest space. A forest canopy's volume and mass are often used in the development of so-called 'carbon markets.'



Once rasterised, for ease of viewing there are also many options for visualising point clouds in ways which bring landscape features into dramatic relief. But, **individual features of a landscape can also be found and separated from the larger point cloud.** For example: a single tree, an archaeological formation, a building, or a road.

While each represents a widely used technique in point cloud analysis, the nature of such analysis varies

developed primarily by specialists focused on archaeological prospection, or the calculation of forest biomass. Such

ways in which landscapes can be related to.

6. Reanalysis

Lidar as a technology has been around since the 1960s. But the use of this technology only emerged widely above forest areas in the early 2000s, alongside the digital point cloud's data standardisation around formats

such as LAS (.las) and the compressed LAZ (.laz) file format for storage, exchange, and archiving. As digital files, the Lidar point cloud can be examined and analysed far away from the original landscapes of reflection.

Point clouds can also be stored, shared, and reanalysed long after the initial Lidar survey. Lidar point clouds are often created in forest surveys organised by governments, universities, Non-Governmental Organisations (NGOs), and companies involved in mining, agriculture, or electric utilities.

Crucially, if accessible, the resulting Lidar point clouds can be reanalysed in the future, for entirely different purposes and by entirely different organisations or people. If available for download on public websites, stored in institutional archives, or discovered on personal devices, point clouds may then be unpredictably reanalysed far into the future.

The practice of point cloud 'reanalysis' refers to the analysis of **Lidar point clouds for new interests in the landscape reflected and recorded by a Lidar system for distinct interests or contexts.** A point cloud created in a few hours decades ago to analyse landslide risks to a community, for example, may be re-analysed at present to search for archaeological ruins, monitor deforestation, or even prospect for mineral resources.

Importantly, even point clouds discovered on aging magnetic tapes have been converted into new data formats such as LAS. Any point cloud found may then prove reanalysable by ever evolving techniques of analysis developed for these modern data formats.

Case 1: Honduras

In 2000, a U.S. agency, the 'Bureau of Economic Geology' (BEG) funded a series of plane-based Lidar surveys across Honduras. The purpose of these surveys was described as the

country following the powerful hurricane 'Mitch', which occurred in 1998. After the project was complete, the point clouds from this project were stored on magnetic tapes in BEG archives. In 2017, researchers from the University of Houston sought out these point clouds for a virtual archaeological prospecting project. Once researchers found the magnetic tape archive where the Lidar point cloud data had been stored years earlier, they reprocessed the point

formats. They then analysed these point clouds for signs of potential

the time of survey. The researchers used both their eyes and point cloud analysis to spot archaeological sites virtually within these point clouds. The researchers then visited the sites

state of the archaeological sites, and

authorities.

Fernandez-Diaz, J. C., & Cohen, A. S. (2020). Whose data is it anyway? Lessons in data management and sharing from resurrecting and repurposing Lidar data for archaeology research in Honduras. *Journal of Computer Applications in Archaeology*, 3(1), 122-134. <https://doi.org/10.5334/jcaa.51>

7. Reanalysis Cases

The reanalysis described above can then occur at any time, if point clouds are recovered following their original analysis. A Lidar point

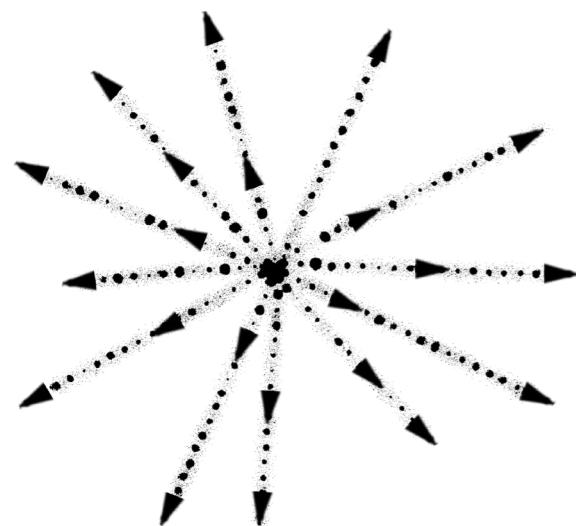
and representation of spaces under tree canopies.

Communities are often **not told** when their land is scanned for a Lidar survey, let alone when, where, and how these point clouds are later reanalysed. This means these detailed visualisations of landscape can be reinterpreted without **community input** long into the future.

Reanalysis is not just a possibility. **It's already happening.** The prospection of point clouds created in the past for new and emergent interests in landscape has been documented in forest areas around the world, many years after their

The following cases involve the reanalysis of point clouds produced by aerial Lidar systems, from two different regions of Central America. This reanalysis occurred years

landscapes were originally collected, recorded, and arranged into Lidar point clouds.



Case 2: Campeche, Mexico

In 2013, a United Nations forest-monitoring program used Lidar to scan 122 km² of tropical forest in Campeche, Mexico. Eleven years later, in 2024, a U.S.-based archaeologist found the point clouds downloadable



online. Once again, the researcher sought out the point clouds created in the original UN Lidar survey for a very different interest in the and reanalysed them on a software program, creating a 'Digital Terrain Model' from the point cloud to archaeological sites. This model's visualisation of the ground under forest canopy in Campeche allowed them the original point cloud created in the UN survey.

Auld-Thomas, L., Canuto, M. A., Morlet, A. V., et al. (2024). Running out of empty space: Environmental Lidar and the crowded ancient landscape of Campeche, Mexico. *Antiquity*, 98(401), 1340-1358. <https://doi.org/10.15184/aqy.2024.148>

8. Why does reanalysis matter?

Whether found downloadable on an online portal, or stored in an archive, point clouds may be accessed years after their creation. Interaction with them may also occur far away from the landscape itself, as digital point cloud across the world.

point clouds created in the past may then draw later interest in the same landscapes in the present. This may occur if the person, group, company, or agency interested in them wishes to locate and access them within the present landscape. This may lead to unforeseen present and future consequences for those

point clouds home. How Lidar point clouds are managed and archived, and who can access them, is then a crucial question.

So, what next?

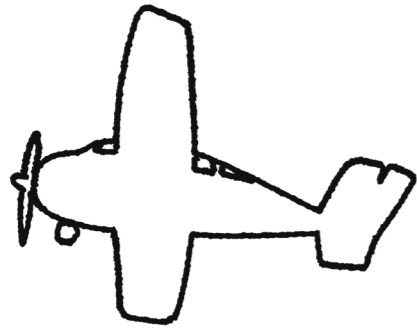
The initial remote nature of reanalysis can leave local decisions and permissions around how forest spaces are accessed, managed, and interpreted more easily ignored, as Lidar point clouds are increasingly relied upon to govern and monitor forest spaces. This may be hugely consequential for not only the living in or around them.

Below are some questions you may want to keep in mind when Lidar surveys are proposed in or around your community. These questions explore how the point cloud will be stored, guide considerations of what purposes surveys may be sought, and probe the likelihood of point clouds being reanalysed in the future.



Ownership & Access

- ◆ Who will have access to the point cloud data?
- ◆ Will it be published online?
Will it be stored in a private archive?
- ◆ How will point cloud data be recorded and stored?
- ◆ Who, or which institutions, will be in charge of these decisions?
- ◆ Will there be shared ownership agreements for Lidar data, co-created with communities local and indigenous to the forest areas surveyed?



Interpretation

- ◆ Who will analyse the point cloud? How?
- ◆ How will access be determined? Will communities living in or adjacent access to the point cloud?
- ◆ Who will be included in the interpretation of what is analysed in the point cloud?

Managing future reanalysis

- ◆ Will the point cloud be reused for new purposes of analysis, such as archaeological prospection, or the measurement of a forest's carbon stock?
- ◆ Will reanalysis be done with community consent, and according to clear conditions of the point cloud data's reanalysis?
- ◆ Are there any limits to how the point cloud will be accessible online for download or stored in archives?
- ◆ Who will be included in the interpretation of what is analysed in the point cloud?

9. Point Cloud Data sovereignty: paths, limits, and possibilities

Digital colonialism foregrounds the collection and management of Lidar point clouds, digital colonialism

"...various inequalities in relation to the internet and other digital technologies and resources between the global 'north' and 'south.' English remains the primary language of most software programs and websites;

harvesting information from the global south; and most software and technological infrastructure is produced in the global north, thus shaping how the global south uses technology."

Thompson, E. L. (2017) Legal and Ethical Considerations for Digital Recreations of Cultural Heritage, 20 Chap. L. Rev. 153.

The inequalities highlighted above may raise concerns about inequalities in the management and access to point clouds after a Lidar survey. Depending on which institution or company manages access to a point cloud, how this data is stored and who can access it will vary deeply. This may motivate communities living in or around the with those who control this access, interaction, and storage.

Efforts to reclaim a community's right to control the production, storage and/or distribution of Lidar point clouds can be understood as movements towards a community's 'data sovereignty.' This term broadly describes the control of protocols around recording, sharing, and accessing data made from or about one's community. Priorities over the type of data a community wishes to exercise 'data sovereignty' over, and how they wish to do so will vary dramatically from community to community.

As highlighted previously in the Campeche reanalysis case, while some point clouds may remain accessible only to those working with or within the companies or the institutions storing them, others may be openly downloadable online.

If data reclamation is not possible, local input into how point cloud data

is managed may be pursued. Beginning conversations about how community input into the distribution and use of point cloud data may involve contacting the institutions or companies which hold the data.

Crucially, if the reclamation of point cloud data is pursued, the goals of community reclamation may range drastically case by case; shared access or access to copies of point cloud data may be one path towards reclamation, while the full control over the access, analysis, and distribution of point clouds may be another path to exercising reclamation.

10. Reclaiming point cloud data: towards data sovereignty

With this in mind, free, and increasingly user-friendly methods of viewing and analysing point clouds from one's computer are growing.

Web-based point cloud viewers such as **Potree** allow one to stream Lidar point clouds in three-dimensions for web-based viewing of the Lidar point cloud.

Further, the open-source and open-access point cloud processing program **Cloudcompare** offers user-friendly point cloud **analysis**. It allows one to not only see the point cloud visualised in three-dimensions, but to point cloud. This, for example, could allow the separation of the under-

area into the aforementioned Digital Terrain Model, or the representation of a particular area of tree canopy of interest.

One may also use Cloudcompare to make details of the point cloud easier to see and relate to. This may be achieved by creating a 'Hillshade'.

This tool allows users to create and change the virtual light-source position (sun direction) in the virtual environment to further highlight details in the point cloud through shadow-based shading.

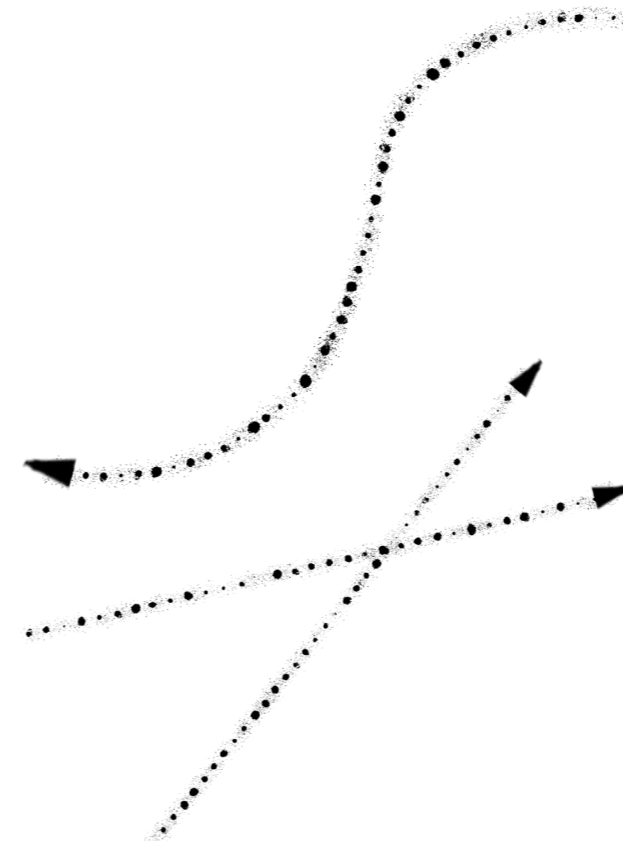
Using programs like Cloudcompare requires one to follow online tutorials, as analysing the point cloud requires more steps than streaming point cloud datasets. This program offers many different language settings, including Spanish.

Exploring each of these methods may open local interaction with point clouds, but it is important to remember some Lidar point clouds can be incredibly dense. Depending on the type of point cloud, the point density of the point cloud and the size of the survey area, these datasets may comprise many gigabytes to several terabytes of data. This means downloading a point cloud may take many hours and require a steady internet connection. The size of the dataset will then depend not only on the size of the landscape surveyed,

point cloud. Point clouds may also be interacted with in smaller sections to ease their download and interaction.

Notably, some analysts can automate the detection of particular landscape features and objects within the point cloud's representation of landscape using machine learning techniques.

powerful machines, programming expertise, and/or the purchase of software that is not licensed for open access.



11. Reclaiming point cloud data: towards data sovereignty

If not downloadable online, to begin conversations about how point clouds may be accessed or reclaimed by community members, contact could be initiated with institutions or companies that control a point cloud's storage, analysis, and access.

If successful, the *long-term* storage of point cloud datasets may be a formidable challenge locally. This can be a particular challenge in areas which face everyday heat, humidity and power instability, conditions that disproportionately affect local stewardship of this data for those living in tropical and sub-tropical environments.

To the right are local options for storing point clouds, each of which vary by price and archival stability. Cloud-based storage is also an option for point cloud data, though it depends on recurring subscriptions and data storage infrastructures subject to terms of access determined by the storage provider.



12. Two Local Storage Options for Lidar Point Cloud Data

Description	Cost	Pros	Cons
*Portable External Hard Drive with USB-C and Thunderbolt access	*USD \$80 per errabyte drive	*Highly portable *Fast data access	*Vulnerable to 'data fade' due to humidity and heat (electric charge based data recording) *Lower archival lifespan compared to HDDs (up to 10 years)
*Portable External Hard Drive with USB-C and Thunderbolt access	*USD \$50 per errabyte drive	*Highly portable *Lower upfront cost compared to SSDs *Longer average lifespan than SSDs (often over 10 years)	*Susceptible to physical damage if dropped due to internal moving parts *Slow access to data

"After all, aren't they talking about producing a 'vision machine' in the near future, a machine that would be capable not only of recognising the contours of shapes, but also of completely interpreting environment close-up or at a distance?"

-Paul Virilio,
The Vision Machine (1994, 59).



