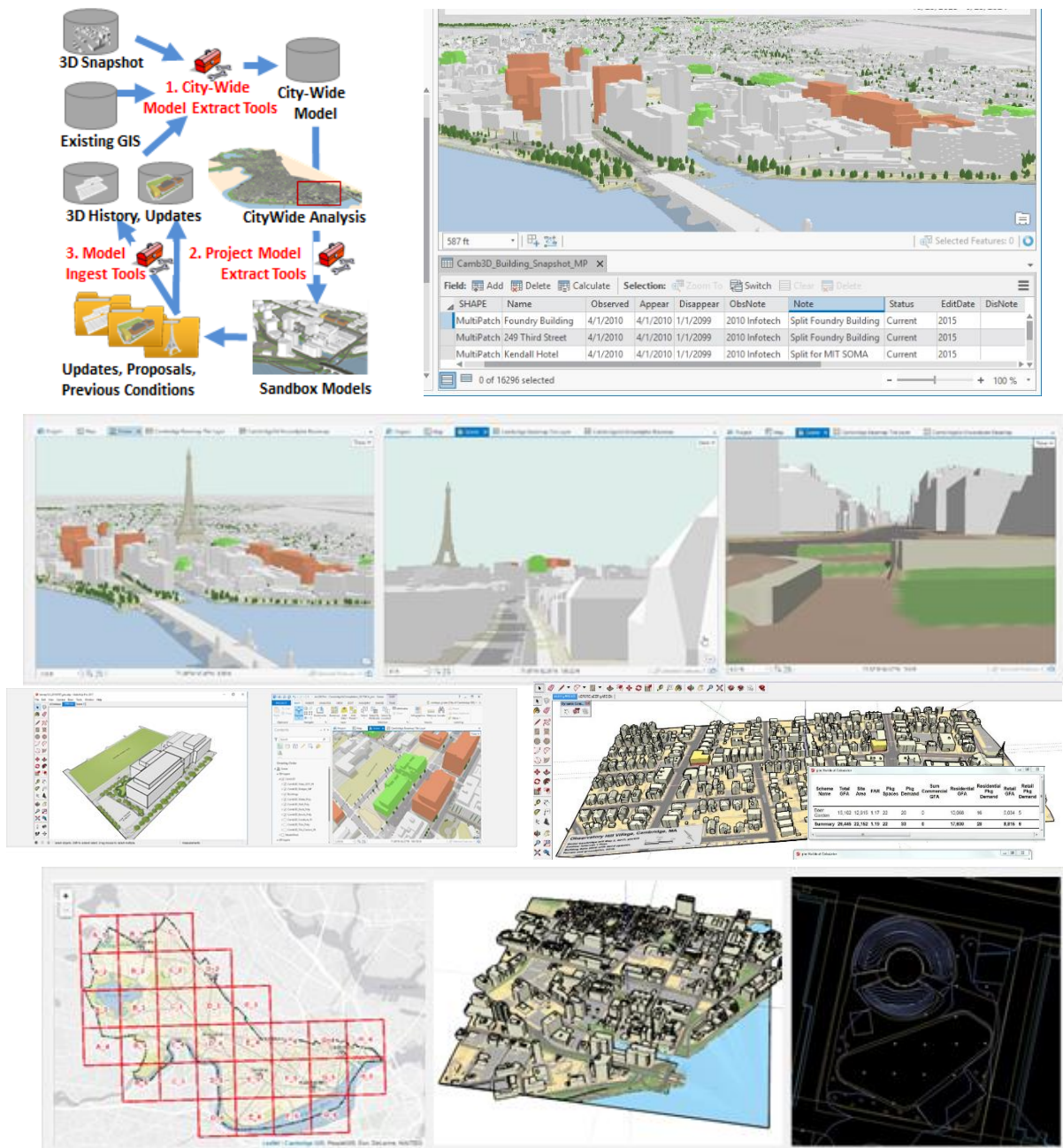


User Guide

Cambridge 3D Geographic Information System



City of Cambridge, Massachusetts
Geographic Information System
July 24, 2017 Accompanying Service Pack 10.

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Introduction & Invitation to Participate

June 29, 2017

This user guide describes the first major revision of an architecture for supporting a 3D city-model within a traditional municipal Geographic Information System. The first edition of the data model was installed on the Cambridge network in 2013.

As an extension of the city's GIS-based information infrastructure, the challenge has been to provide straight-forward extensions to a traditional GIS data infrastructure that will reflect the current state of the three-dimensional city; for exploring alternative futures while also retaining information about past conditions as the model is updated.

Thanks to the collaboration of Cambridge city staff and other collaborators, this new architecture and user-guide addresses several challenges were exposed during our trial period concerning the management of a city model that is used and updated by users across different offices within city-government and the greater design and development community.

We hope that data managers in other cities can benefit from reading this user guide and will share their experience with us as we continue to improve this data model.

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City of Cambridge 3D GIS User Guide

This document introduces an architecture for extending a municipal geographic information system for the management of a three-dimensional city model. The system adds a few tables and feature-classes to the simple relational database management architecture familiar to city staff and provides workflows for exchanging data with tools that are familiar in the world of urban design and development – where 3D context models are very useful and where new 3D data originates.

Figure 1 illustrates the lifecycle of data in the city-wide 3D model. The city-wide model is generated from the city's existing GIS layers and some additional 3D building data. This city-wide model is used for city-wide visualizations and serves as a source for clipped-out editable context models, known as **Sandbox Models**. Sandbox models provide a context for creating and assimilating new information from design applications. Finally, new models are imported into the GIS-based city-wide model. The tools and methods that connect each of these stages make it possible for the GIS staff to maintain a model of a living city made up of diverse contributors using a variety of tools, as illustrated in **Figure1**.

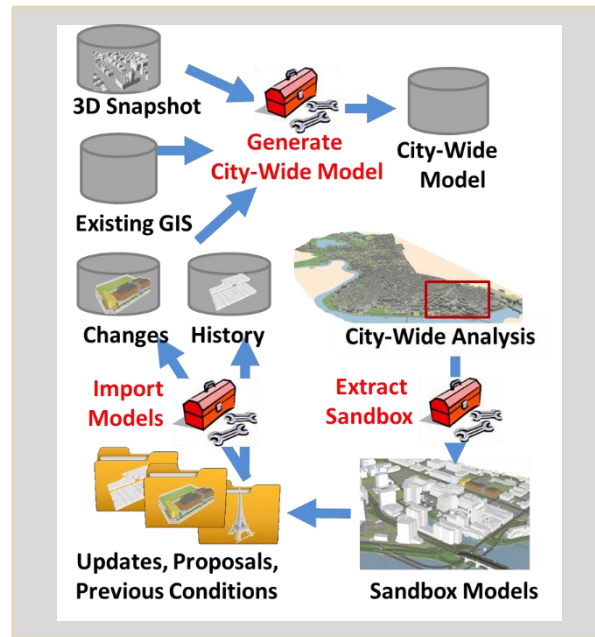


Figure 1: Cambridge 3D GIS Architecture

This user guide accompanies a zipped archive, **Cambridge3D_20170629_pbc.zip** which contains the Cambridge3D data model and a set of tools for generating the model and for managing each of the **workflows** indicated by the toolboxes in **figure 1**.

Take the Tour

This tour of the Cambridge 3D GIS will alternate between exploring the data and applications in ArcGIS Pro and exploring the way that the data and tools as organized in the Cambridge3D project folder,

Extract the Cambridge3D Project

Right-click on the zip archive and extract it to your local file-system. The zip archive holds a single folder with several sub-folders as depicted in **Figure 2**.

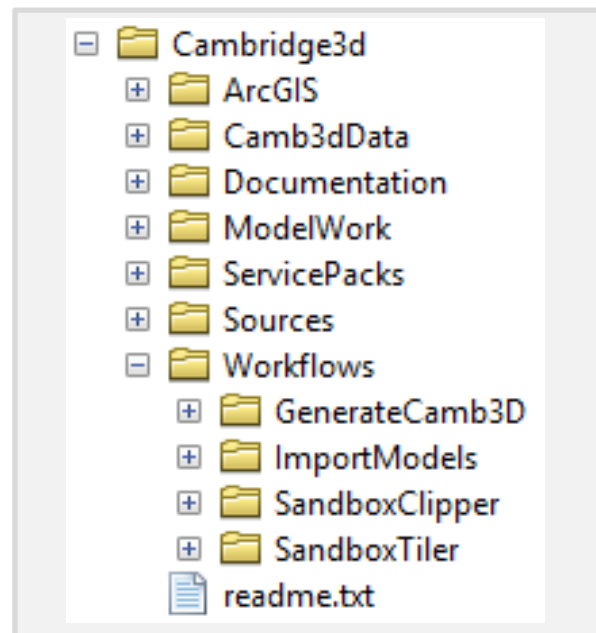


Figure 2: The Cambridge3D Project and its Folders

Folders in the Cambridge3D Project:






The Cambridge3D project is designed to be self-contained. The project archive includes all the source data, and the tools and documents that are needed to demonstrate each of the workflows. This “Mother Model” is intended to be shared on the city’s intranet and to be more-or-less read-only; writable by an administrator or two. Users are encouraged to start their own independent development projects to carry out their own versions of the template workflows to generate custom sandbox models or to make updates to feature classes and tools. Updates to the model are kept in sync across different users through service packs that are applied by the model administrator at either site. Between service packs, the latest zipped archive is a full backup of the current state of the Mother Model.

While exploring the data and applications below, it will be helpful to keep your eye on the file management conventions established in the Cambridge3D mother model its template workflows. Understanding the names and purposes of these folders will enable contributors to quickly find and share data, documents and tools. **File Management Guidelines** are explored in detail in a later section of this user guide.

Introducing the Folders

Before looking at the data in action, take a few minutes to explore the Cambridge3D project folders using your file browser.

Cambridge3D/

-  **Documentation:** Contains the documentation for this project, including this user-guide and a document providing step-by-step instructions for each of the workflows that play a part in managing the Cambridge 3D GIS data model.
-  **ArcGIS:** Contains documents intended to be opened with ESRI software. The documents found here are intended to represent the latest compilations of the layers in the Cambridge3D project. If updated versions are created in here, they should have the current date and user’s initials appended. Normally, these documents are opened and then immediately saved somewhere else to avoid messing up these templates.
-  **Sources:** Contains data that are used by the documents and tools in the Cambridge3D project but which originate elsewhere. Data in this folder are organized in folders according to the name of their originating source
-  **Camb3dData:** Contains the data that are created within the Cambridge3D project. The datasets in this folder are created by the **GenerateCamb3D** workflow which will be discussed in more detail below. For more complete metadata about these datasets, see the Cambridge 3D Data Dictionary document in the **Documentation** folder.
-  **ModelWork:** Contains the source documents for hand-made models that become part of the Cambridge3D GIS. The **ImportModels Workflow** document explains how these are organized.

Workflows:

- **GenerateCamb3D:** Contains the tools, documents and folder structures to create each of the layers in the Camb3DData folder. Whenever changes are made to the Camb3D schema, the tools in this workflow should be updated.
- **ImportModels:** Contains the tools, documents and folder structures for importing new 3D models into the multipatch feature classes.
- **SandboxClipper:** Contains the tools, documents and folder structures for clipping sandbox models from the city-wide model.
- **SandboxTiler:** Creates the city-wide tiled sandbox models in various formats for downloading on the web and for situating updates for the multipatch
- **ServicePacks:** the place to store incremental updates to the Cambridge3D project. The organization and the function of these folders is discussed in **File Management Guidelines** section, later in this user-guide.

Explore Project Data and City-Wide Visualizations in ArcGIS Pro

The **ArcGIS folder** contains compilation documents composed with the ArcMap, ArcScene and ArcGIS Pro. These documents reference all the layers of the Cambridge3D data model, including source data. It is expected that these map and scene documents will be updated periodically to reflect new layers as they are added; so each document has the date of the last revision in its name and the initials of the person who last revised it.

Open the ArcGIS Pro document, **Cambridge3dCompilation.aprx** in the ArcGIS folder. Begin by looking the layers in the 2D map document accessible with the **Map** tab.

Groundplan and Infotech 2010 Planimetric Data

Expand the **GroundPlan** group layer in the ArcPro table of contents. The Groundplan layer is comprised of several layers from the 2010 Infotech planimetric survey -- the foundation of much of the current Cambridge GIS. This survey, based on stereo photogrammetry, supplied detailed information about edge-of-pavement, pavement markings, terrain, walls, docks, street trees (without heights), traffic signs and signals and litter-baskets, and benches. Building footprints with height information for the drip-

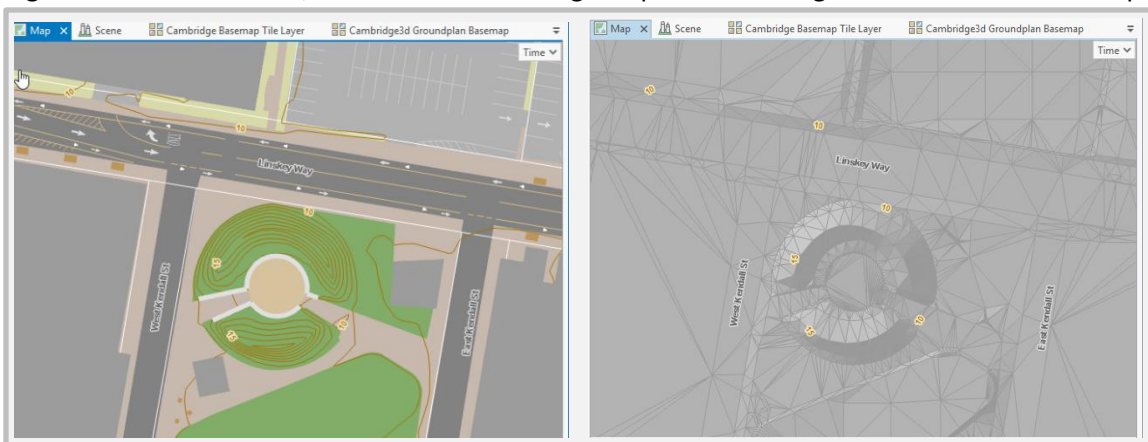


Figure 3: The Groundplan and Terrain Layers in ArcGIS Pro.

lines and highest points on buildings were also collected. A few of these layers have been modified with tools in the GenerateCamb3D workflow.

The **Surround** group layer extends a simplified groundplan for the areas that lie beyond the Cambridge City Limit. The Surround plan is made with several layers from **MassGIS**. Together, the layers in the Groundplan and Surround group layers provide the base-map for of the city-wide 3d model. It is usually draped on the terrain model as a compiled raster image.

Explore the Cambridge3D/Sources Folder

Most of the layers in the Groundplan and Surround groups reference data-sets that originate outside of the Camb3D project. Even though most of these exist elsewhere in the City of Cambridge file system, they are included within the Cambridge3D archive so that the tools and documents that incorporate the data are portable and can be developed and demonstrated both at the pbcGIS headquarters and at the city.

Data that originated outside of the Cambridge3D project is organized in the **Cambridge3D/Sources folder**. Look in the Sources folder. Data in Sources are organized according to the company or agency from which the data were obtained.

The City-Wide 3D Data Model, Camb3dData

Open the **Camb3dData** Group layer in the ArcGIS Pro table of contents. These are the layers that make up the city-wide 3D data model. Notice that each of the layers, and the names of these layers begin with the string **Camb3D**.

Many of the Camb3D layers are generated from the Infotech planimetric data. Operations such as creating a triangulated terrain model, finding the elevation and heights of trees, walls, and street furniture are performed using the tools in the **GenerateCamb3d** workflow, which will be discussed in more detail below. If you are wondering where these Camb3D data can be found, look in **Cambridge3D/Camb3dData**. A more detailed explanation of each of the layers in the Camb3D city-wide 3D model, you may consult the **Camb3d Data Dictionary** which can be found in the **Cambridge3d/Documentation** folder.

Before leaving the 2-D world, look at the terrain models in the **Terrains** Group layer at the bottom of the **Camb3dData** group layer in the ArcGIS Pro table of contents. Notice how the triangulated TIN edges conform logically to the edges of paved, built, and landscaped areas in the Infotech groundplan.

Explore the City-Wide, Camb3D Data in 3D

To really appreciate the Cambridge 3D GIS, this tour will now switch ArcGIS Pro to 3D mode. Click the **Scene** Tab in the ArcGIS Pro document.

Terrain and GroundPlan

Visit the bookmark named **Sky Bowl** to get a look at the terrain in 3D. The Camb3D terrain model is based on elevation points and break-lines from the 2010 Infotech survey. It is accurate to about a foot and meets the buildings, walls and other features in a very clean, logical way, as shown in **Figure 4**. This terrain model is used to assign base-heights to all the other Infotech layers. LIDAR information from 2009 was then used to estimate the heights of the street trees.

The relation between terrain and the groundplan looks great when you use the

Cambridge3D_Groundplan. But it is much faster to use the **Cambridge Basemap Tile Layer** (hosted on ArcGIS On-Line) as the base-map in your ArcPro scenes. If you are on a fast computer or have more time, you can choose the Cambridge3D Groundplan as your basemap (one of the map tabs at the top of your scene.)



Figure 4: The Cambridge3D Terrain Model

Multipatch Feature Classes Hold Bridges and Buildings

To explore the 3D buildings, fly out to the bookmark named **Kenny Longfellow**. Open the **Camb3D Data** group layer, and the sub-group named, **Buildings**, notice several of the layers have names that end with the letters “**_MP**.” These are Multipatch feature classes that store true 3D models as GIS feature classes. Treating 3D models in relational database tables allows us to have many, many models in a single scene.

Most of the building models were created by a company named Cybercity3D, Inc using the 2010 stereo photography. A round of updates was made later using imagery from April 2014. These models are included in the **Camb3D_Building_Snapshot_MP** feature class, which serves as the current snapshot. At this writing, this snapshot reflects the state of buildings as of April 2014. As updates are added, this layer may be retired as **Building_Snapshot_2014_MP**.

Buildings that are in various stages of the proposal and approval pipeline are represented in the **Camb3D_Buildings_Proposed_MP** layer. Some of these buildings are under construction and some have been built. Eventually some of these models may become part of an update to the current building snapshot.

As the city develops, buildings are demolished or subject to substantial renovations. Even though these buildings will no longer be part of the current snapshot, it would be irresponsible to simply delete and forget them forever. Before deleting buildings from the current snapshot, the multipatch features are copied to the **Camb3D_Building_History_MP** feature class.

The layer **Camb3D_Bridges_MP** stores models of bridges, some of which have been shared by SketchUp users on Trimble 3D Warehouse file-sharing community.

Multipatch Attributes

Each of the multipatch layers shares a common schema of attributes, that can be seen at the bottom of **Figure 5**. These attributes provide information about when the building first appears in the historical record, when the building was demolished, the building's status, i.e. Proposed, Approved, Built or Demolished. These attributes make it easy to prepare before-and-after visualizations for single buildings or long-term development projects with multiple phases. This schema that interacts very well with the time-slider in applications like ArcGIS Pro, as illustrated in **Figure 5**.

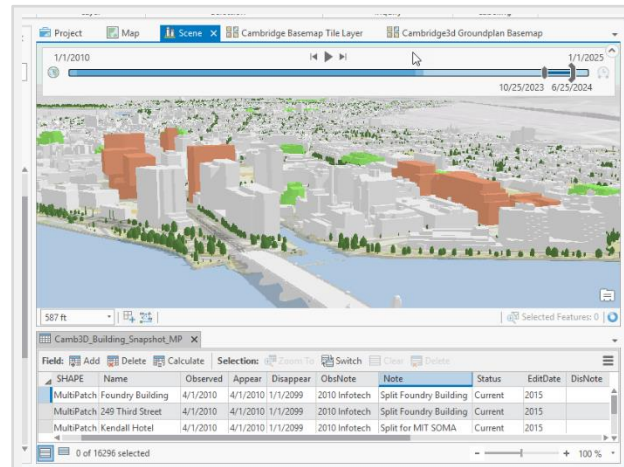


Figure 5: 3D Layers interact with the Time-Slider

Play with the Time Slider

To appreciate the organization of current, proposed and approved buildings in ArcGIS Pro, choose the Kenny Longfellow bookmark and reveal the Time Slider by clicking the Time button in the upper right corner of the scene window. Sliding the time window back and forth selectively renders or suppresses the rendering of buildings in the Building Snapshot and Proposed Buildings layers.

City-Wide Visualizations

An example of incorporating a new model into a city-wide visualization, scroll down the ArcGIS Pro table of contents and open the **ModelWork** group. Check the box next to the Eiffel_Volpe layer. This model was inspired by a hypothetical proposal made by a city council member that Cambridge should consider building a 1000 foot tower in this site. Informal studies like this are easy to insert into the city-wide model to explore distant views. Fly to the ArcGIS Pro Bookmark, **344 Broadway**, to see how this fictitious scenario would alter the skyline as seen from a third-story window at the Cambridge City Hall Annex, or use the **Harvard Square** bookmark to investigate a more distant view.

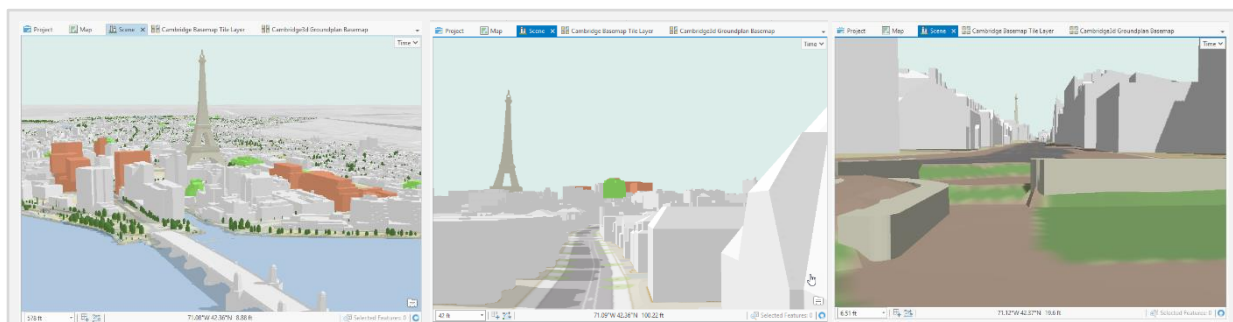


Figure 6: 1000 Foot Volpe visualizations: Bird's Eye View, 344 Broadway and Harvard Square.

Editable ModelWork Stored in the ModelWork Folder

The source material for hand-made models is saved in the Cambridge3D file archive in case these models need to be revised. Take a look in **Cambridge3D/ModelWork**. The workflow and tools for adding new models to the city-wide 3D model schema is described in the **ImportModels Workflow** document.

City-Wide ArcScene Document

ArcScene is not as good as ArcGIS Pro at twirling the entire city-wide model, but it does have one big capability that Pro does not: It can generate stand-alone CityEngine web-scenes. These web scenes are not as broad in scope as streaming ArcGIS-On-Line scenes, but The City-Engine projects offer much more control to toggle alternate arrangements of buildings, and having no dependence on layers hosted on ArcGIS on-Line.

If you want to try this for yourself, open the city-wide ArcScene compilation in ArcScene document, . **Figure 7** is a view from a WebScene produced from this ArcScene document. To create your own web scene, Use File > Save As to make your own copy of the document, turn off all layers except for the groundplan, and use the Area of Interest Tool to choose the area of interest. This view may be turned into a web Scene using the [Export 3D Web Scene](#) tool from the Geoprocessing toolbox. The resulting webscene can be published on ArcGIS On-line or any web server. Click here to [view the interactive web-scene](#).

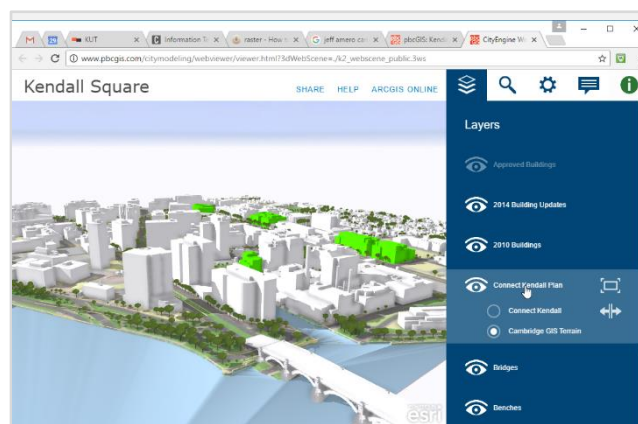


Figure 7: City Engine WebScene Exported from ArcScene Document

The Master ArcMap Compilation

The tool-sets at the heart of each of the template workflows have been developed and tested in ArcMap 10.4.1. The ArcMap document **Cambridge3D/ArcGIS/Cambridge3dCompilation.mxd** is the document is the template document that references all of the data-sets that these workflows need. Each of the tool-sets uses a local version of this map document. When updates are made to the Cambridge3D schema, this master document should be updated to reflect the changes.

Data Transformation Workflows

The intention of this section of the user-guide is to provide an executive-level understanding of the workflows that are supported by the Cambridge 3D GIS. These will be discussed in terms of their general application here. For deeper reading each workflow has its own step-by-step user-guide included in the **Documentation** folder.

Open the Cambridge3D/Workflows folder. There are four folders inside. Each folder contains a collection of tools and ArcMap documents and other folders set up to transform or extract information

from Sources and the Camb3DData folder. The workflow projects all use relative path names to reference Sources and Camb3dData form the mother folder, and to write their results into folders inside the local workflow project. To demonstrate or apply one of these workflows the user first copies it to his or her own development folder somewhere outside of the mother project. Each of the workflows has its own step-by-step Workflow How-To document in its Documentation folder with all of the gory details. We'll provide an executive summary of each of the workflows, below.

Clipping Sandbox Models

While GIS-based tools offer advantages for managing very large data-sets with tabular feature-classes, designers prefer to create and experiment with scenarios with tools that are more hierarchical in their organization and more flexible and fluent for manipulating geometry in 3D. The Cambridge 3D model includes a tool-set for clipping portions of the city-wide model exporting it to formats that are compatible with design tools. These clipped models are called **Sandbox models**.

Sandbox models provide a context for design studies, and a platform for creating updated building and bridge models that can be imported into the GIS-based model management system. The Sandbox tool-set uses a user-created rectangular frame to clip out a sub-set of the appropriate layers from the city-wide model. These clipped datasets may be transformed into design data formats using an FME workbench, or imported into ESRI's City-Engine.

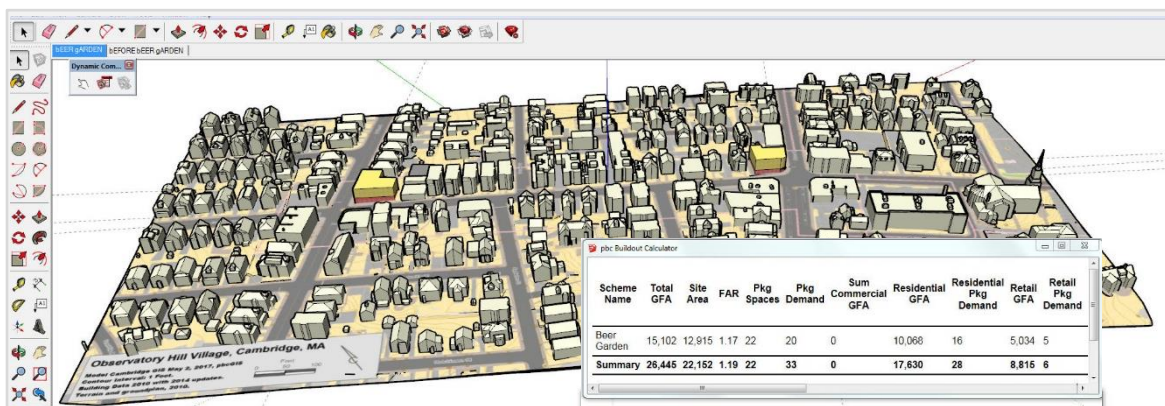


Figure 8: Concord Avenue Sandbox Model

Figure 8 depicts a sandbox model created to support design studies associated with the zoning petition focused on a few blocks of Concord Avenue. For more details on how clip out sandbox models, see the **SandboxClipper Workflow** and the **Camb3dCityEngine Workflow** Documents.

Importing New 3D Models

Georeferenced SketchUp models (such as the ones created with the **SandboxClipper** workflow, provide a context for creating new models or for assimilating models submitted according to our **Model Submission Guidelines**. Once a new model has been created or placed into a georeferenced sandbox model, it may be exported as a KMZ format file that is easily imported into a GIS multipatch data-set.

KMZ models are easily imported into one of the multipatch feature classes of the Camb3DData schema using the tools and techniques discussed in the **ImportModels Workflow** document. Figure 9 depicts a development prepared according to the **Cambridge 3D Model Submission Guidelines**.

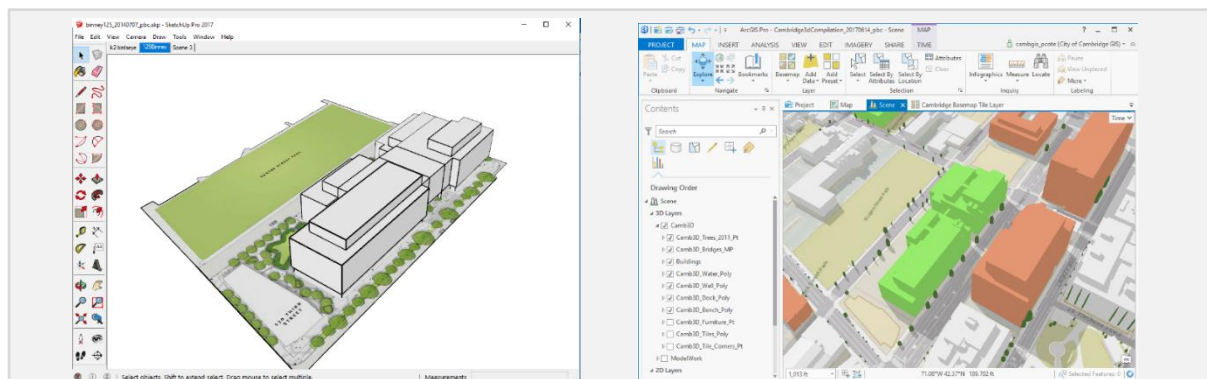


Figure 9: A model ready for import to the Camb3d_Building_Proposed_MP feature class.

The Tiled City Model

To make the entire city model accessible to designers and the public, the FME-based **SandboxClipper** tools have been automated to produce sandbox models for the entire city, cut into tiles of one kilometer square. These tiled sandbox models are available from the city's web site, 3D download page. Formats include: georeferenced SketchUp format, COLLADA and DXF. **Figure 10** shows the city-wide sandbox tiling scheme. Generation of the tiled city model in these formats is accomplished with the **SandboxTiler** toolset.

Creating or modifying 3D layers with the Generate Camb3D Workflow

As you learned in our initial tour of the Cambridge 3D GIS, many of the layers in the city-wide 3D model have been derived from the 2010 planimetric survey by Infotech. There will come a day when some of these layers might be refined. For example, the width of some of the walls near the river might be



Figure 10: The city-wide, Tiled Model Download System

widened to make the seawall look better. The person wanting to make this modification will want to find the procedure that was used to turn the original wall centerlines to 3D polygons in the first place. Whenever modifications are made to these layers they should be carried out by modifying the tools that generated the layer in the first place. These tools are found in the GenerateCamb3D workflow. The procedure for cloning this too-set, making modifications and posting these back to a service pack are discussed in detail in the GenerateCamb3D Workflow document.

Data Management and Model Administration

The **Cambridge3D_20170630_pbc.zip** archive contains a snapshot of the Cambridge 3D GIS and its sources and workflow tools as of June 29, 2017. When installed on the City of Cambridge LAN or on the super-computers at pbcGIS headquarters, the data and workflows of the **Mother Project** are used as read-only resources as users go about creating sandboxes, importing new 3d models or even refining new features in their own development folders.

User Development Folders

Figure 11 depicts the way that individual development projects are started anywhere on the LAN in a **user development folder** that we will call **User3D**. My User3D folder is named **pb3D**. Most development or sandbox projects begin by copying one of the template workflow folders from the mother project to **User3D/Workflows**. These projects reference data in the mother project by default. If new hand-made models are created, they go into **User3D/ModelWork** folder. If new or improved data-sets are created for the Camb3D Geodatabase, these are put into **UserDev/Camb3dData/Camb3D.gdb**. When tools are improved or added, the toolbox in the local project is renamed with a new date and the author's initials.

Service Packs

When it is time to commit changes to the Mother Model, a user can make a list of the changes, and create a service pack by simply copying the UserDev folder and removing any files that are not part of the update. In any case, the folder structure of the service pack has a folder structure that makes it clear where each update is to be copied.

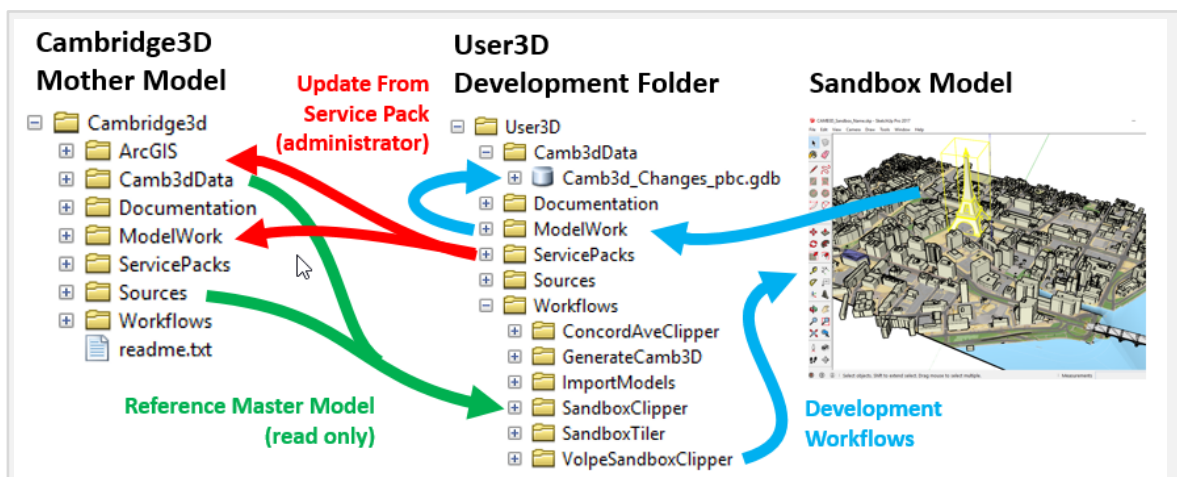


Figure 11: File Management View of Model Lifecycle

Once everything checks out, a new zip archive of the entire Cambridge3D folder can be made and dated as a full-image back-up. Between service packs, it is easy to keep the changes-in-work backed up by simply backing up each user's development folder.

Syncing independent instances

In cases where two or more instances of the Cambridge city-wide model might exist; for example, at pbcGIS headquarters and on the City of Cambridge network, these distributed projects can be kept in

sync either with the exchange of an entire zip archive of the Cambridge3D data model, or by means of several individual files or projects packaged with instructions as a service-pack. Each workflow document includes instructions on how to place new or changed data into a service pack.

💡 We may want to investigate doing this sort of versioning and syncing with GitHub.

Workflow-Specific User Guides

Now that you understand the overall architecture of the Cambridge 3D GIS project, you may be ready to tackle some of the techniques. Take a look in the Documentation folder to find step-by-step instructions for all of the technical workflows required to clip out sandbox models or to develop the city-wide model by importing new models.

Here is a list of the specific user-guides included:

- **Cambridge 3D User Guide**
This user Guide
- **Generate Camb3D Workflow**
Use this workflow to find and revise the tools that generate the city-wide model from sources
- **SandboxClipper_Workflow**
Use this workflow to clip out sandboxes for any rectangular extent. Sandbox models may be opened in ArcScene, CityEngine or exported to Sketchup or AutoCAD DXF.
- **Sandbox Tiler Workflow**
This workflow uses a tile-grid and some FME Workbenches to automate the generation of sketchup models for the whole city-wide model. Sandboxes are processed in several formats for downloading on the web.
- **3D Model Submission Guidelines**
Draft guidelines for project proponents wishing to submit project models for incorporation in the Cambridge 3D GIS.
- **Import Models Workflow**
Use this workflow to import georeferenced models created in a Sketchup sandbox into one of the Cambridge 3D GIS multipatch feature classes.
- **CityEngine Sandbox_Workflow**
This workflow document explains how a sandbox model can be imported into CityEngine and transformed with a collection of custom-made CGA rules.