Developing, Maintaining, and Sharing
A Collection of Georeferenced Building Models

Cultivating a Living Ecosystem of:

- Shared resources
- Diverse Contributors and Tools
- Diverse Users and Applications

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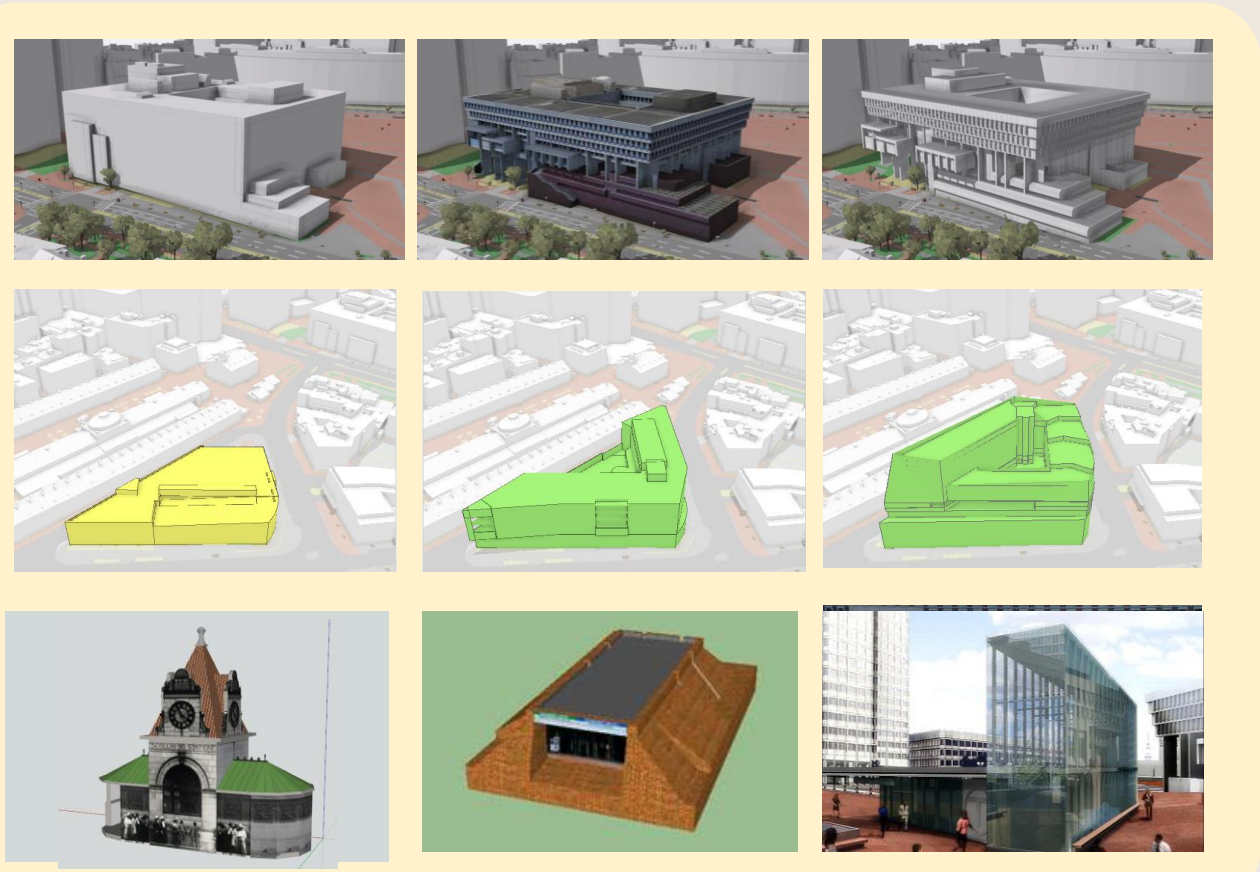
With valuable assistance from
Te-Ming Chang and Piaotian Jin
Boston Planning and Development Agency

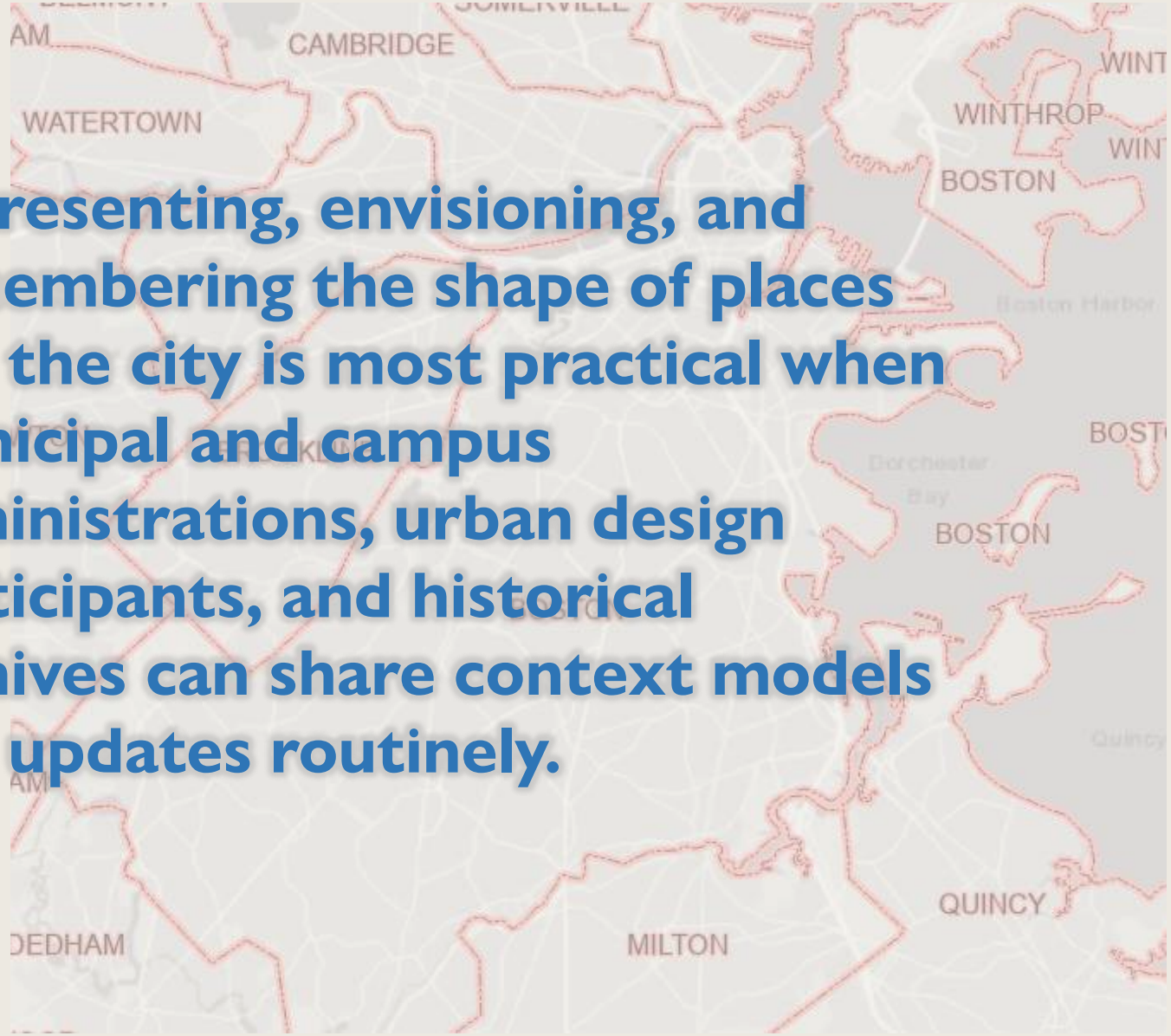
ArcGIS Urban User Group April 4, 2021



pbcGIS: Cultivating Spatial Intelligence™

Acknowledgements: A Regional Collaboration

This project began at the Harvard Graduate School of Design around 2002 with data from the Massachusetts Geographic Information System. Over the years it has received sponsorship, and collaborative support from the Harvard Center for Design Informatics, the Boston Redevelopment Authority, the City of Cambridge, Town of Brookline, The Open Geospatial Consortium, The Massachusetts Institute of Technology Facilities Department, Harvard University Planning and Real Estate, Sasaki and Associates, Architects and many others.



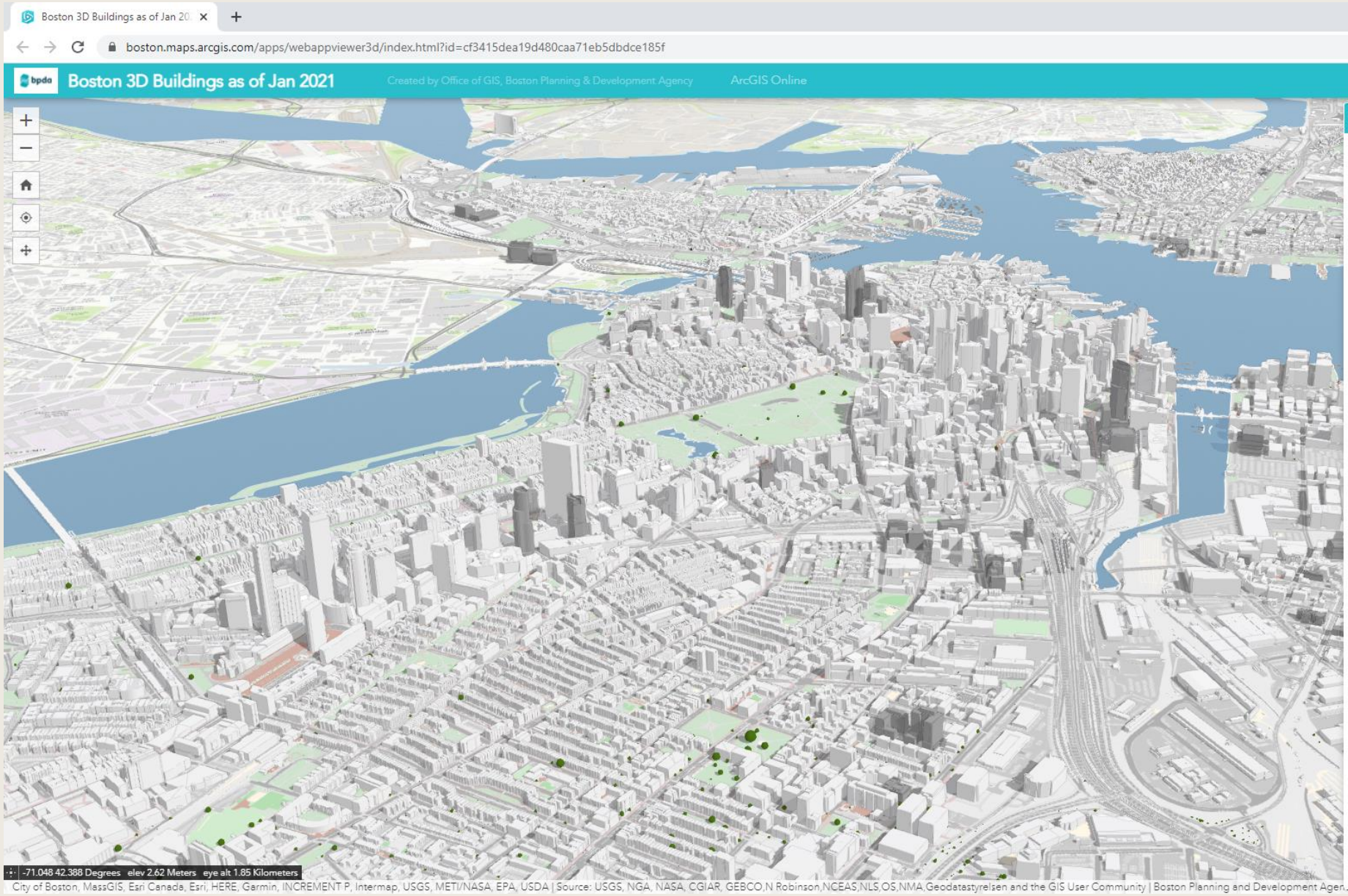
Representing, envisioning, and remembering the shape of places and the city is most practical when municipal and campus administrations, urban design participants, and historical archives can share context models and updates routinely.

Boston's Virtual Twin

The Boston Planning and Development Agency GIS department maintains a 3d city model that is available for the public to fly through and explore on their web site at

www.bostonplans.org/3d-data-maps/3d-smart-model/citywide-3d-model

This web-based, interactive fly through is created using ArcGIS On-Line from ESRI.



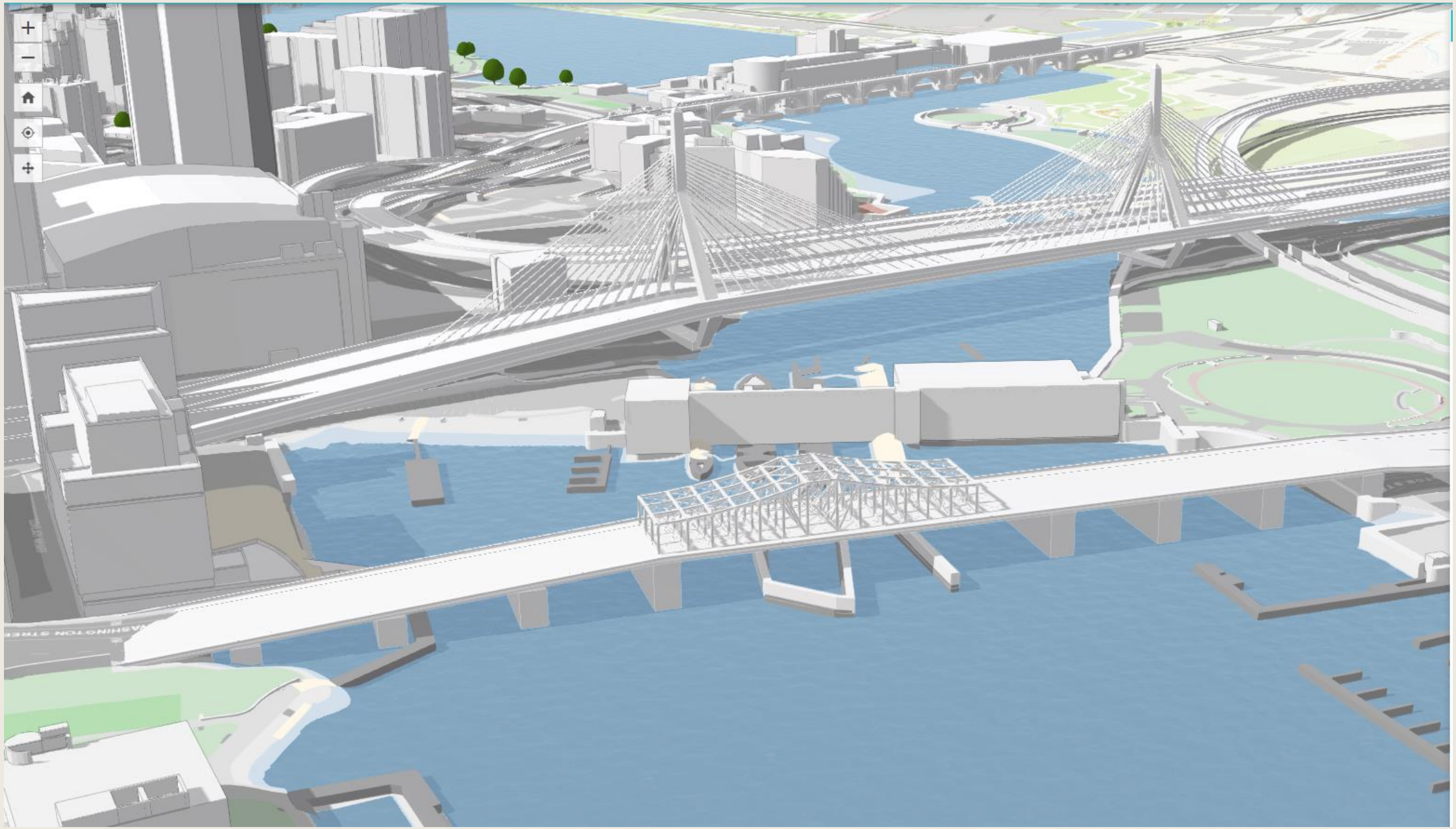
A collection 130,000 individual 3D models

The model consists of a detailed terrain and groundplan and about 130,000 3d models representing structures: Buildings, Building Groups, Building Parts and Bridges.

Most of the 3D models were collected via stereo photogrammetry and reduced to crisp 3d models by either extruding building roof-prints or through a more elaborate process that preserves roof detail, carried out by CyberCity3D.

Models of major development projects created since 2011 have been created by hand by the BPDA's Urban Design Technology group led by Te-Ming Chang. Who also created some beautiful bridge models.

A collection 130,000 individual 3D models



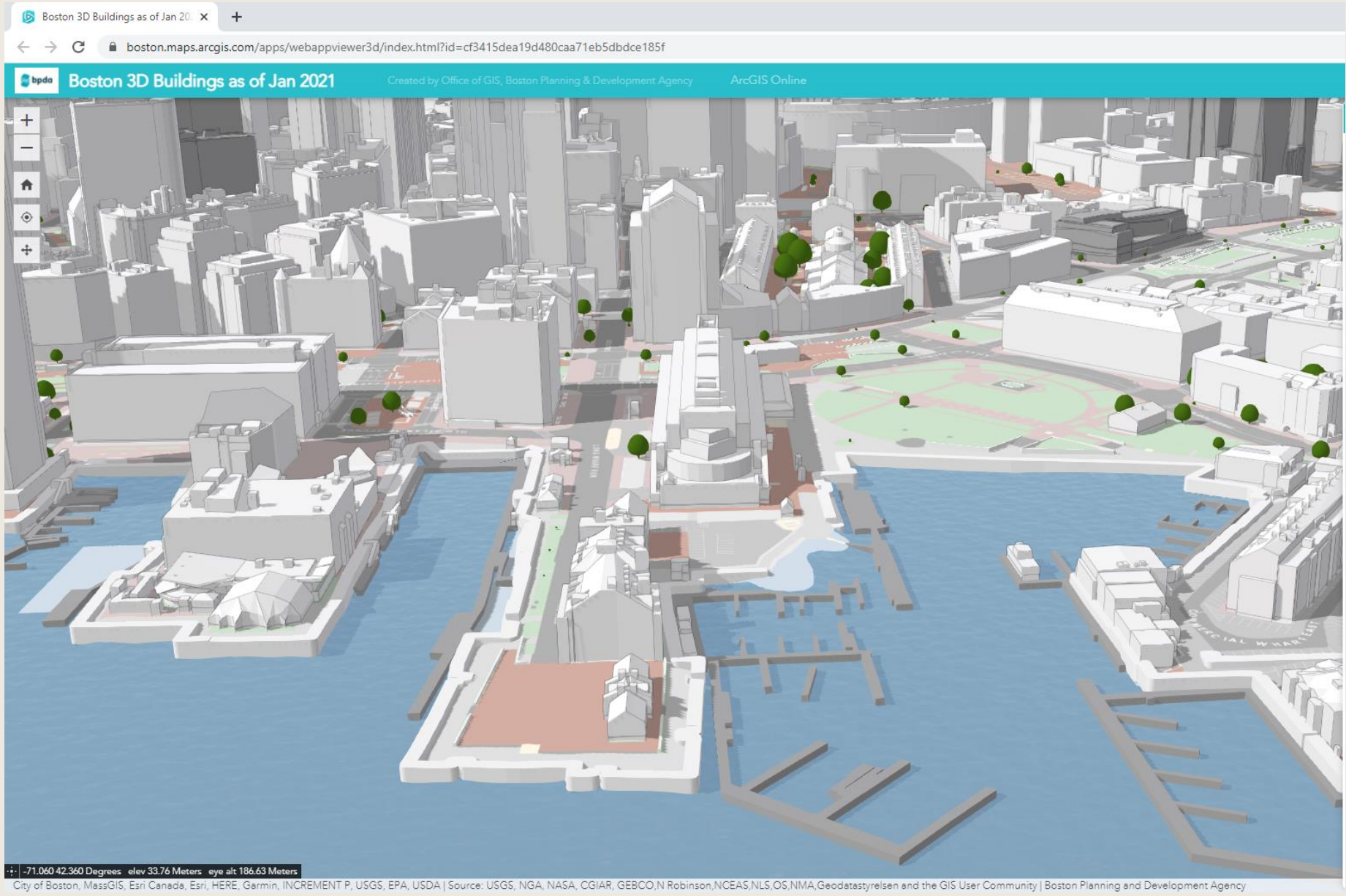
Original Model Development

The terrain and groundplan and other details, building footprints including walls and floating docks were captured in a 2011 photogrammetric survey and reduced to 2.5-Dimensional geometry (polygons with heights) by InfoTech.

Infotech also provided a concise, but detailed digital terrain model with breaklines and masspoints.

pbcGIS turned adapted these data to create an integrated 3D model.

Part of the process was to use extruded polygons for walls, docks and buildings and replace the extruded buildings with more detailed models for CybeCity3D where available.

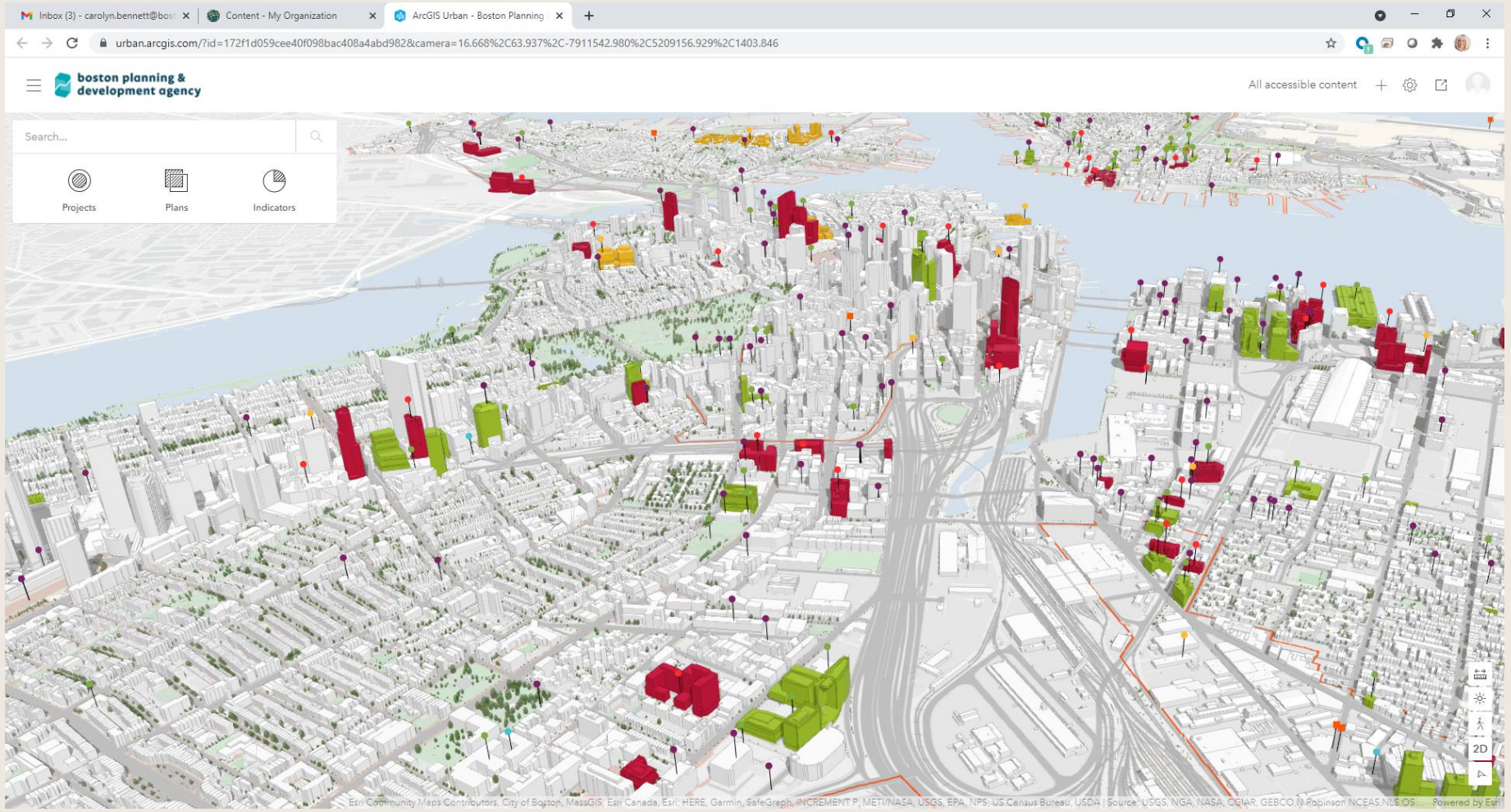


On-Going Model Curation

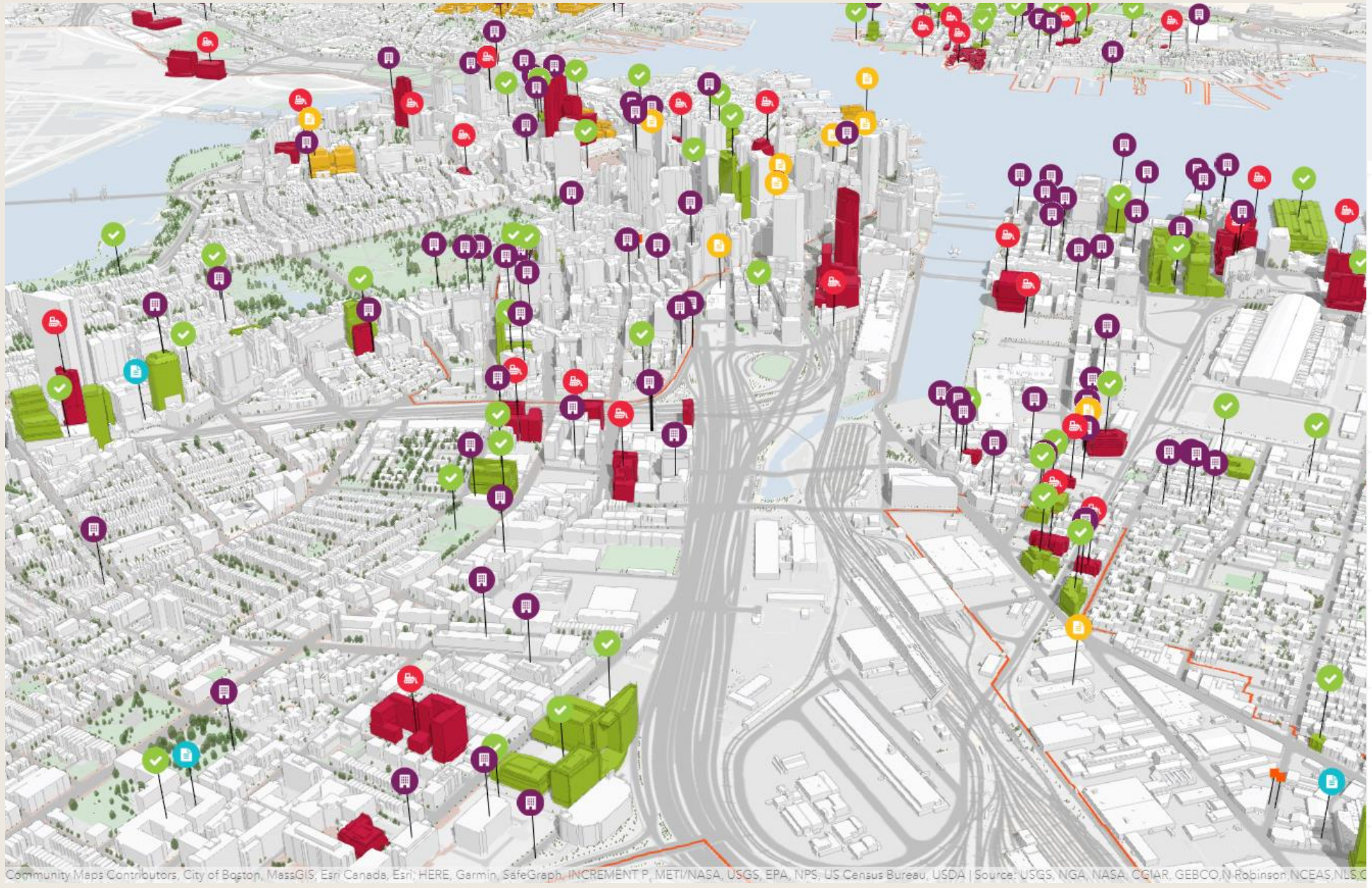
The design review process in Boston results in 3D models being created for most large projects. Models are contributed by deveopers or created by the BPDA Urban Design Technology Group (UDTG)

As projects proceed through the review process the BPDA GIS department updates the status attributes of models.

Keeping the digital twin in sync with the current condition and allowing for representation of alternative future, also requires managing the status and archiving models of models from the past and models of structures that might be replaced or modified.

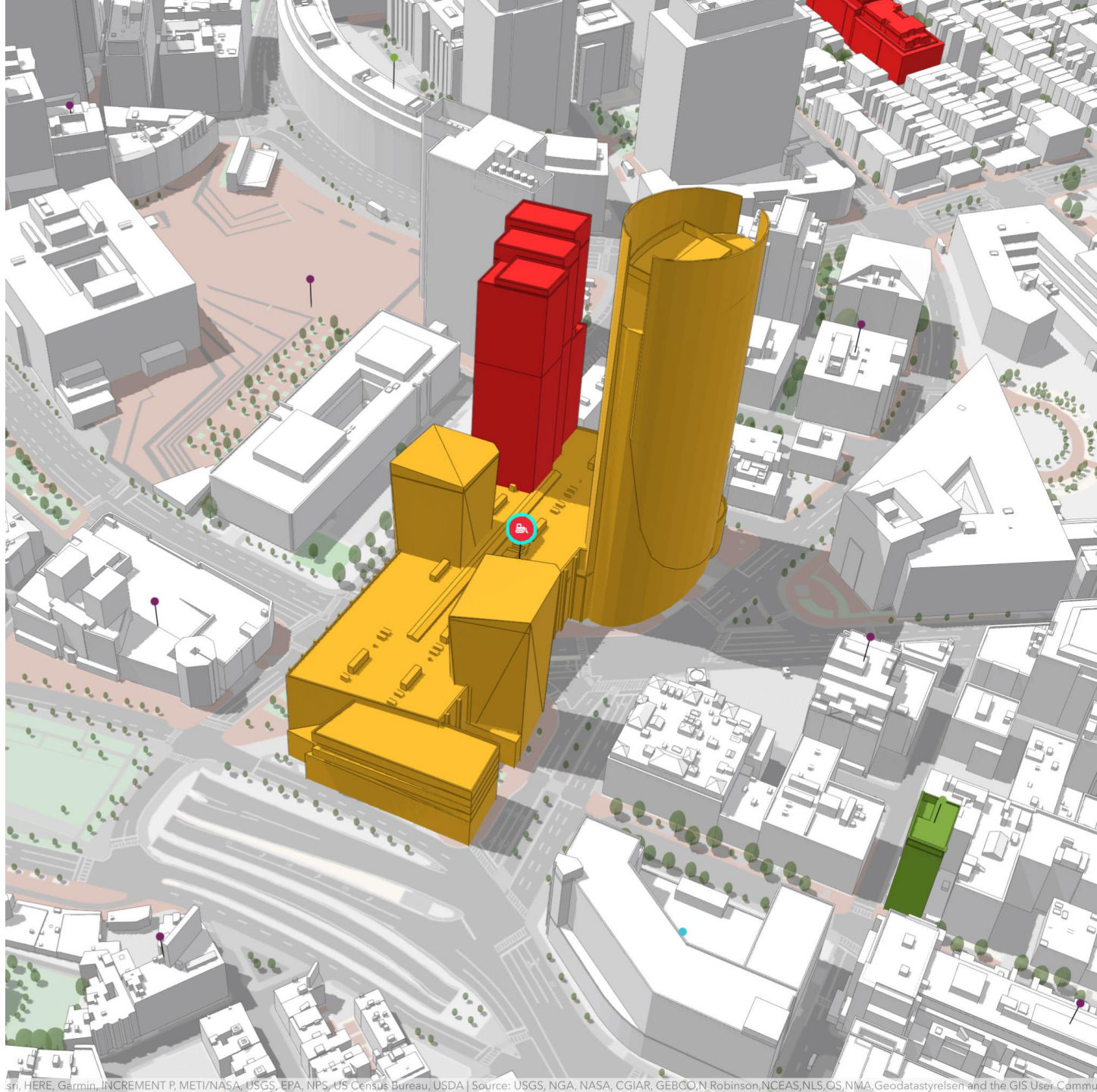


Planning Applications in ArcGIS Urban



Visualize Projects Citywide

Visualize, track, and review development projects throughout their lifecycle.



Inbox (3) - carolyn.bennett@bost | Content - My Organization | ArcGIS Urban - Boston Planning

urban.arcgis.com/projects/d623e2c489c14e3fa3c0beed0528c8dd/b4fe84c2-38ae-481d-8728-736171b71242?id=172f1d059cee40f098bac408a4abd982&camera=208.633%2C73.176%2C-7910680.874%2C5213466.879%2C145.008

boston planning & development agency

All accessible content

Projects

← Back to List

0 | Open

Project - Under Construction

Shawmut Avenue/Washington Street Block

The Shawmut Avenue/Washington Street Block project will include three (3) buildings with a combined total maximum of 660,456 square feet of Gross Floor Area (the "Proposed Project"), and would include approximately 536 residential units, of which at least 139 would be income restricted.

The project site encompasses 100 Shawmut Avenue (192,600 sf), 50 Herald Street (263,100 sf), and 120 Shawmut Avenue (161,516 sf). 100 Shawmut is Phase 1 of construction.

August 28, 2017 | March 1, 2023

Project webpage

Developing and Sharing the 3D Model Collection

Enabling Contributors: Where do Building Models Come From?

Building models can be created by wholesale processes of observation:

- Photogrammetry
- LIDAR

Reduction of vast amount of 3D data to Concise 3D Models

Calibrated level of detail

Articulation of individual buildings or functional spaces (difficult!)

The most interesting models for planners and are hand-made using 3D modeling software

Design Tools:

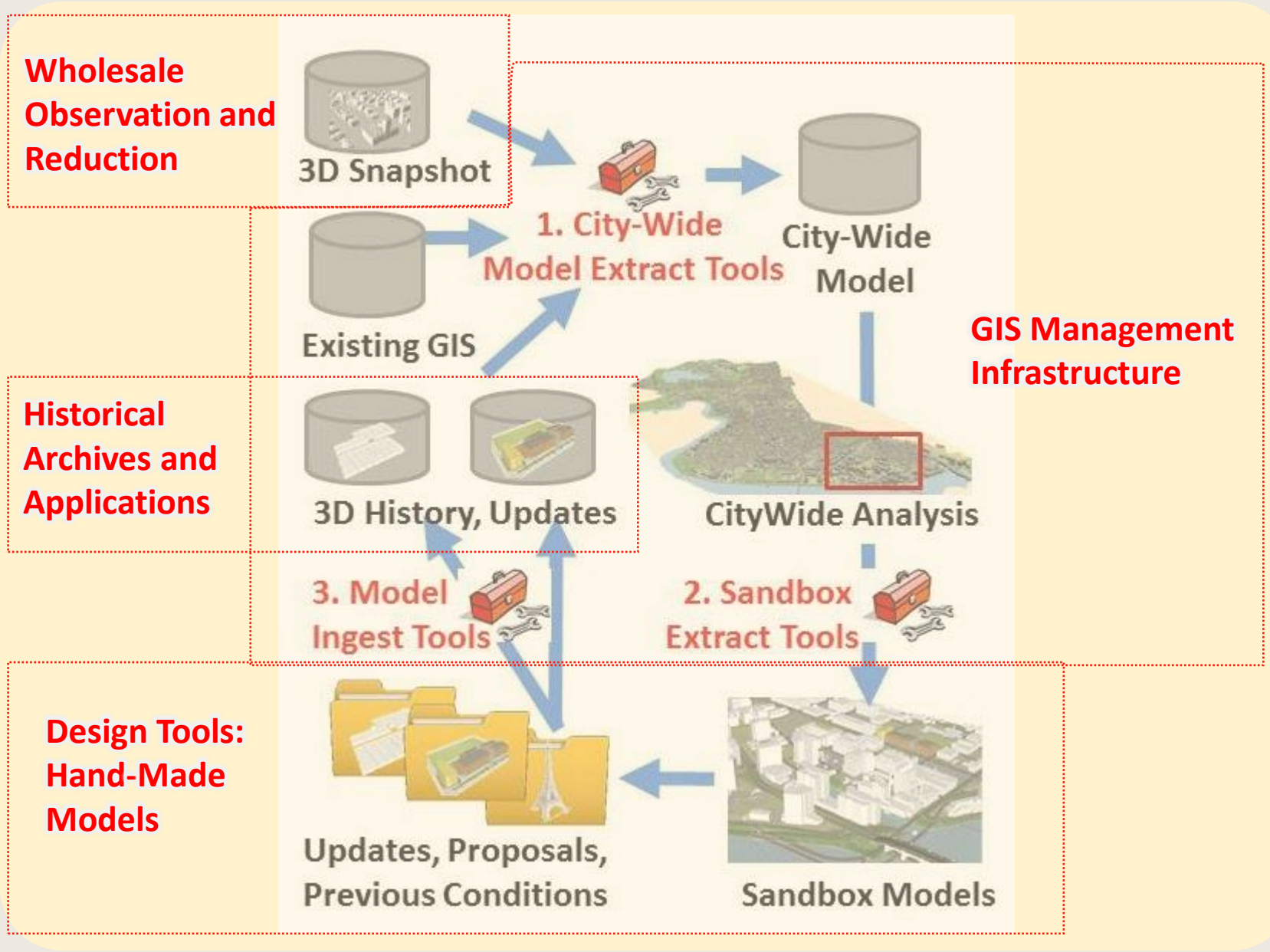
- Deep object hierarchy: Grouping
- Coordinate Systems are limited in spatial scope.

GIS Tools

- Flatter Relational tables
- Extensible Spatial Scope

Strategy for Collection Development:

- Provide context models compatible with Design Software
- Round-Trip Import and Export of models with Design Software



Contributors and Authority Are Distributed

- Campus in-holdings
- Neighboring Municipalities
- Design and Development Firms

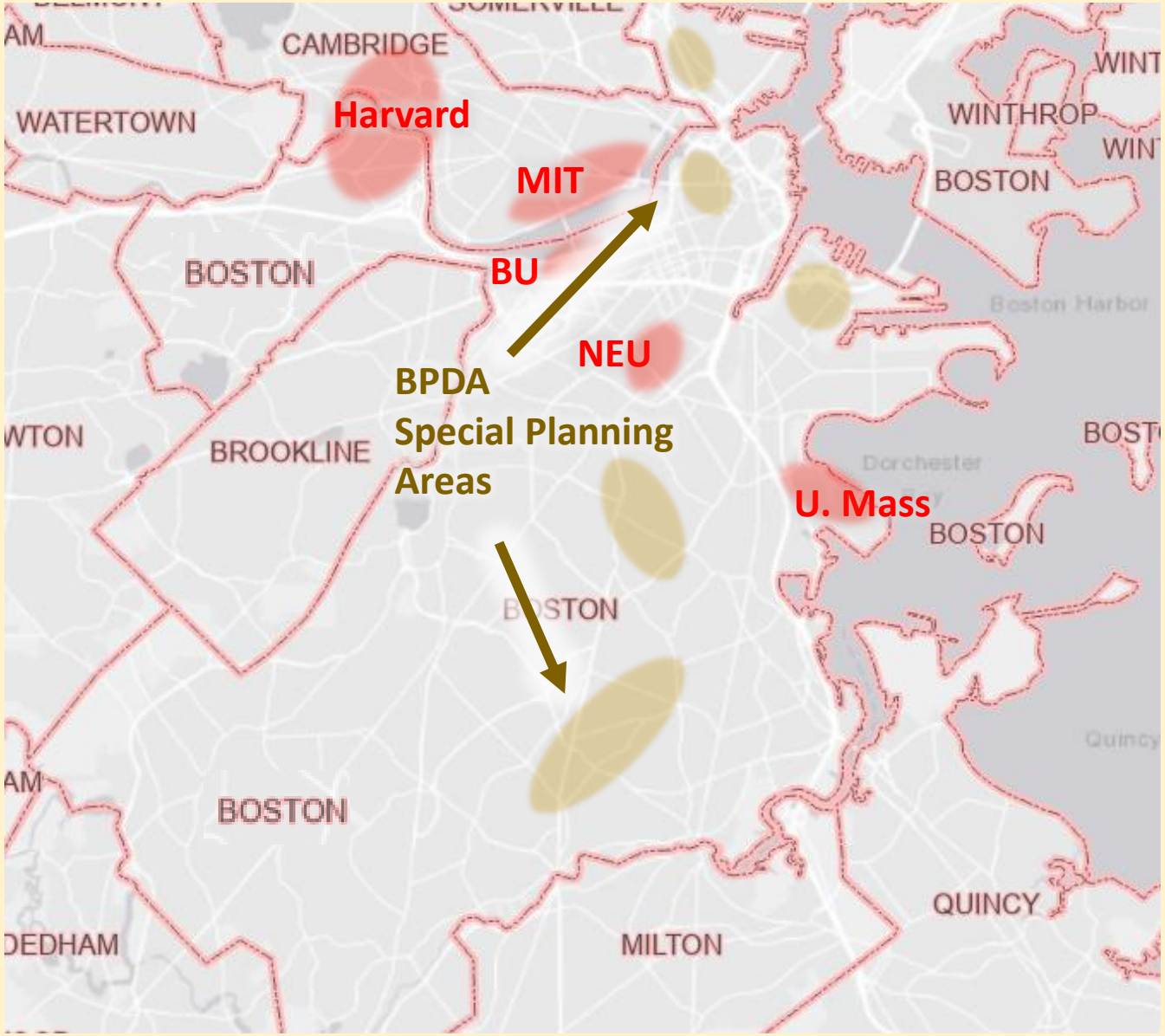
Each of these contributors wants to have their own piece of the city model, as a context for their own model development.

- Private
- Overlapping
- Always in need of updating

A large part of the cost of developing a city model lies in the design of data architecture

- Schema:
- Attributes Segmentation
- Tools
- Development and Management of resources (workflow & sharing)

These costs are THE reason that successful regional 3d collaborations are not happening.



Models came From Multiple Sources

Date of observation

Method of observation

- Photogrammetry / LIDAR
- Maybe Based on Design Drawings
- Determines level of detail

Editorial / Artistic Decisions by Modeler

- Automated or Human

A single building may have many alternative models

Name: Boston City Hall
Link: Wikipedia
Status: Current
Status Class: Active
Appear: 1965
Appear Source: MACRIS
Model Credit: Cybercity 3D
Model Date: 2013
Survey Source: From April 2010 photogrammetry by Infotech

Name: Boston City Hall
Link: Wikipedia
Status: Current
Status Class: Alternative
Appear: 1965
Appear Source: MACRIS
Model Credit: Google 3d Team
Model Date: 2013
Survey Source: Unknown methodology or sources. Shared through 3d Warehouse.

Name: Boston City Hall
Link: Wikipedia
Status: Current
Status Class: Alternative
Appear: 1965
Appear Source: MACRIS
Model Credit: Parsons Brinckerhoff
Model Date: 2005
Survey Source: Unknown methodology or sources.

The Present Condition and Ideas about the Future

Developing Ideas for the Future

- Design in Context
- Comparison in Context

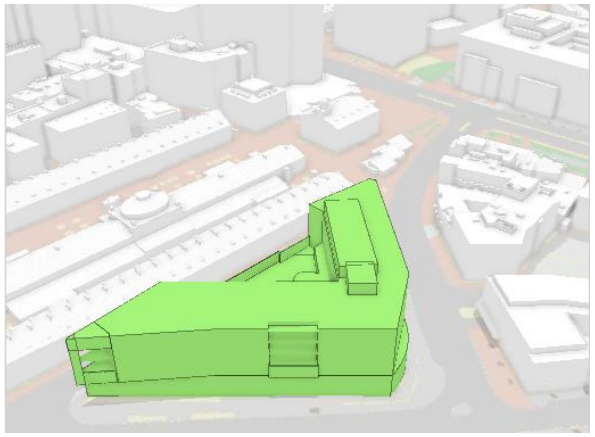
Once Approved and Permitted, Design models stand in for future buildings.

Models of demolished buildings must not be simply deleted!

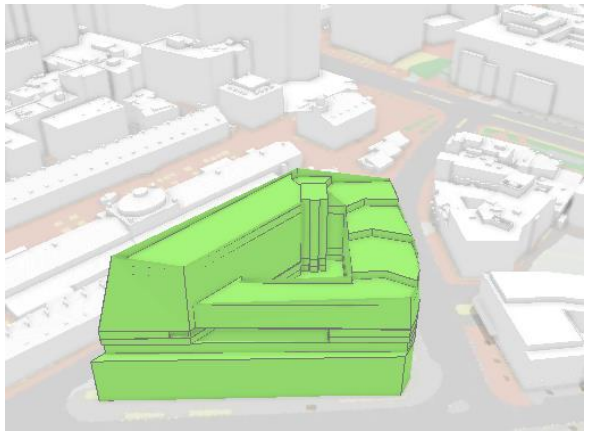
Record the dates and observation sources for regulatory and lifecycle milestones (Status)

Preserve models of alternate design ideas as historical documents

Name: 20-30 Clifton St
Link:
Status: Demolished*
Status Class: History
Appear: 1980
Appear Source: Boston Assessing, 2020
Disappear: April 1 2020*
Disappear Source: Building is gone per NearMap April 2020*
Model Credit: Cybercity 3D
Model Date: 2013
Model Info: From April 2010 photogrammetry by Infotech



Name: Proposed Dock Square Garage
Link: BPDA Project Page
Status: Superseded Proposal
Status Class: Proposals
Appear: June 13, 2019
Appear Source: Article 80 Log
Disappear: December 19, 2020
Disappear Source: Article 80 Log
Model Credit: BPDA Urban Design Technology Group
Model Date: June 1, 2018
Model Info: Modeled from drawings



Name: Approved Dock Square Garage
Link: BPDA Project Page
Status: Under Construction*
Status Class: Active*
Appear: December 19, 2020
Appear Source: Article 80 Log
Model Credit: BPDA Urban Design Technology Group
Model Date: December 12, 2019
Model Info: Modeled from drawings

**** Fictitious values for illustration only***

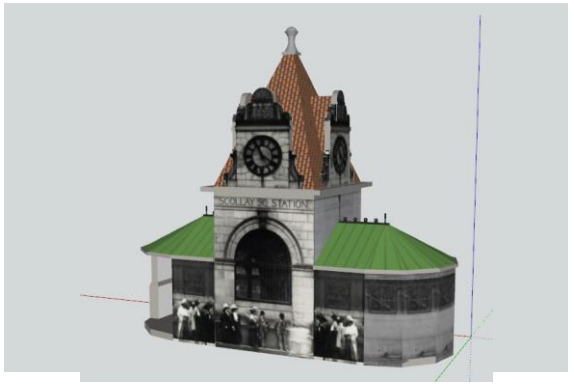
Preserving / Developing Historical Model Assets and Knowledge about Places

Recent historical models are a by-product of the model management workflow.

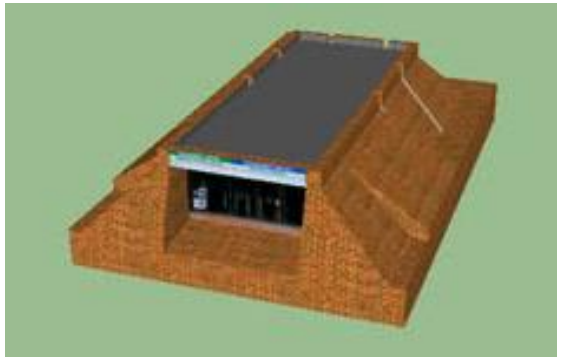
- Don't delete models of buildings that are demolished
- Try to preserve historical photogrammetry information

Hopefully, a model management infrastructure will make historical modeling much easier and more common:

- Free georeferenced context models
- Relieved expense of figuring out how to integrate, preserve and share assets.



Name: Scollay Square Subway Kiosk
Link: Web Page by David Russo
Status: Demolished
Status Class: History
Appear: 1898
Appear Source: 1898 Bromley Atlas
Disappear: 1927
Disappear Source: David Russo
Model Credit: Paul Cote
Model Date: 2009
Model Info: Modeled from historic photos, Geolocated per



Name: Government Center Subway Headhouse
Link:
Status: Demolished
Status Class: History
Appear: 1968
Appear Source:
Disappear: 2016
Disappear Source:
Model Credit: Paul Cote
Model Date: June 1, 2008
Model Info: Modeled from photographs.

Name: Government Center MBTA Station
Link:
Status: Current
Status Class: Active
Appear: December 19, 2020
Appear Source: Appears as finished NearMap April 2018

The model of this new station and alternate proposals are yet to be collected.
Hopefully, this collection wil be routine in the future!

Model Management Schema

3D Our schema for managing building and bridge models has been years in the making

- Developed in collaboration with Cambridge, Boston and Brookline
- Designed to be used by various towns and campuses
- Foresees an ecosystem of linked data archival and discovery tools

Segmented according to Status Class

- Keeps working model light-weight
- Preserves proposed, alternate and historical models
- Each feature class uses an identical schema

Many fields are populated through automatic model enrollment process

Tolerant of incomplete information

- Problems with model lumpiness and cardinality
- Provides a place for recording knowledge when it is available

3D Models Data Dictionary
Bridge / Building / Project Attributes
Model Status Attributes (According to controlled domain)
Model / Survey Provenance Attributes
Model Geometric Attributes (Automatically generated)
Links to useful reference information (Automatically generated)
Editor, Edit Date, Edit Action (Automatically generated)

Download most recent schema design document, data dictionary and geodatabase template at www.pbcGIS.com/boston3d

Multidisciplinary Participants in Model Collection Development

3D building models are different from ordinary vector GIS Data

- Models originate from many sources and formats
- Necessary stakeholders use a variety of tools with particular limits and capabilities

Anticipating the long-term, end-to-end model development strategy is worthwhile to ensure that value and effort are sustainable.

Municipal & Campus GIS

- **Transform Formats**
- **Integrate wholesale observations**
- **Act as local model curator**
- **Regional model contributor and source for updates**

Regional 3D Model Collection

- **3D Models of Buildings Bridges and Trees**
- **Model-specific metadata**
- **Tiled Terrain**
- **Tiled Groundplan images**
- **Aggregated over time and across geographical territories**

Model Contributors

- **In-house planning studies**
- **Submissions for Project Review**
- **Neighboring municipalities and Campuses**
- **Students, Hobbyists, Historians**
- **Use a variety of design-oriented modeling tools. (flexible grouping, limited coordinate space)**

Archival and Historical Apps

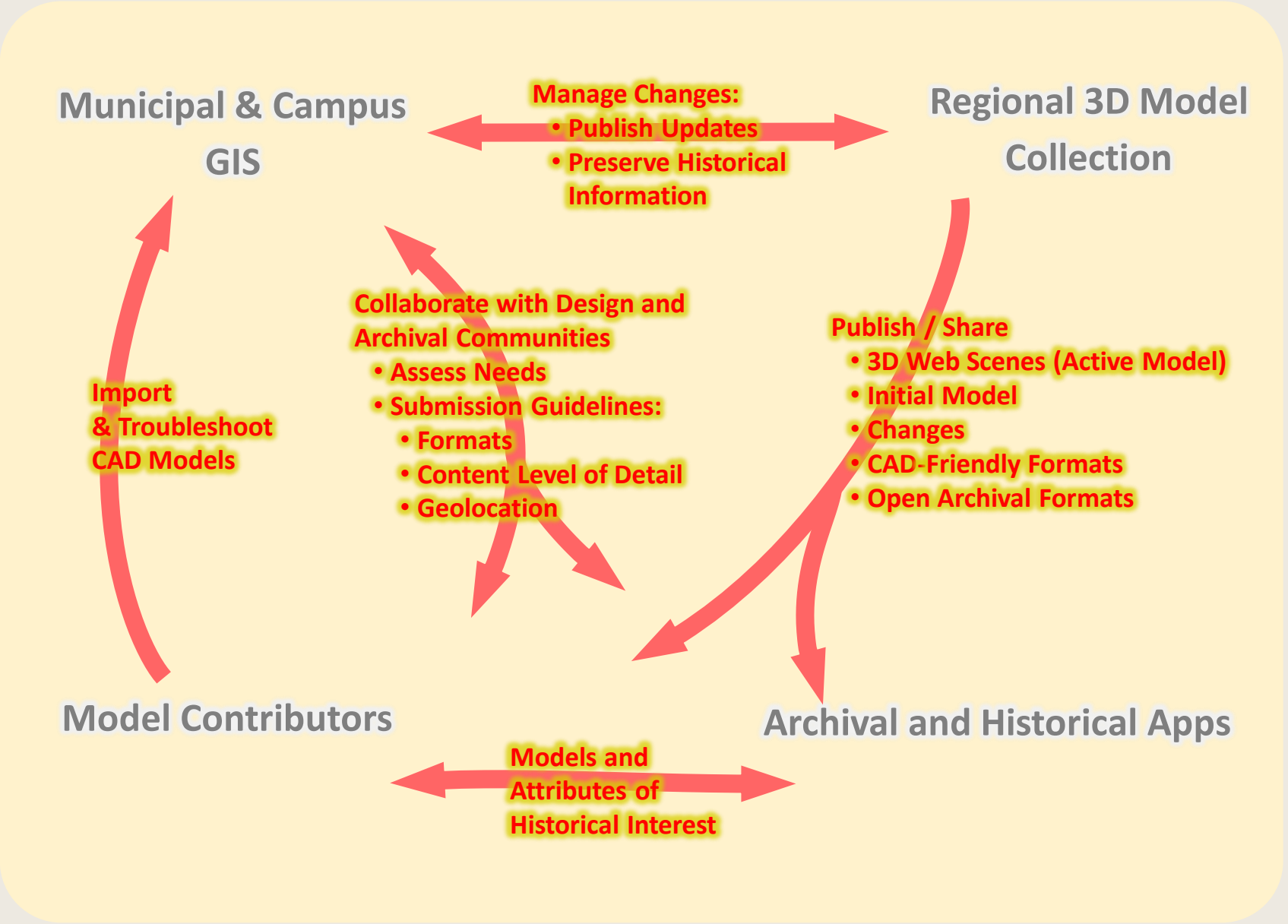
- **Long-term Data preservation**
- **Connecting models and other historical resources**
- **Deepening information about structures**
- **Employs data architecture and standards that facilitate linking, discovery and augmentation**

Planning the Lifecycle of Assets in a Collection of 3D Models

The process of working through all of these transformations is VERY costly!

- Unexpected problems lurk around every corner
- Discovery of new problems calls for adjustments in the architecture and prior-steps in the tool-chain.
- The process of designing these workflows end-to-end has taken a lot of time and collaboration with experts form GIS, Design and Library Science fields.

The latest documentation of our design process can be found at
www.pbcGIS.com/boston3d



Provide Detailed Context and Geo-Location for 3D Model Collaborators

Inter-Operatng with 3D Modeling Tools

- 3D models can be gathered wholesale from LIDAR or photogrammetry and provided in Geodatabase format.
- Models of proposed buildings or historic buildings originate in 3D modeling tools that are preferred by designers.
- BPDA uses Safe Software FME to publish the model collection with detailed terrain and groundplan information tiled in formats that are easy to import into common 3d modeling tools
- To maintain georeferencing it is necessary to share models in a shifted state plane coordinate system.
- Our model submission standard provides an easy way of exchanging updates with collaborators with a minimum of adjustment necessary.
- Despite the best laid plans, 3d modeling skills come in handy when troubleshooting problems with models.

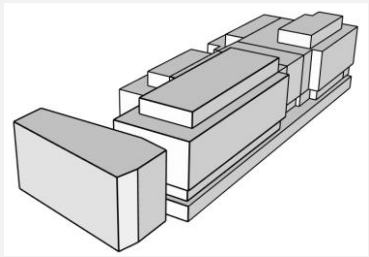
Try it yourself at the BPDA 3D Download Page!

3D Model Submission Guidelines and Georefrencing

Our tiled model exports are issued using a shifted State Plane Coordinate system that avoids problems with 3D modelnig tools that have problem with the number of digits in un-shifted coordinates.

The tiled models provide a context for locating new models that can be automatically shifted back to State Plane coordinates when imported into GIS

The preferred format for exchange is Wavefront Object format (.OBJ) which is a stable open format that is imported and exported by almost all popular modeling tools



Simple Building Shell

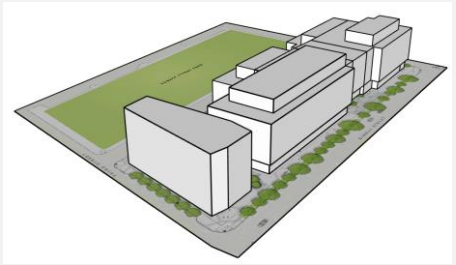
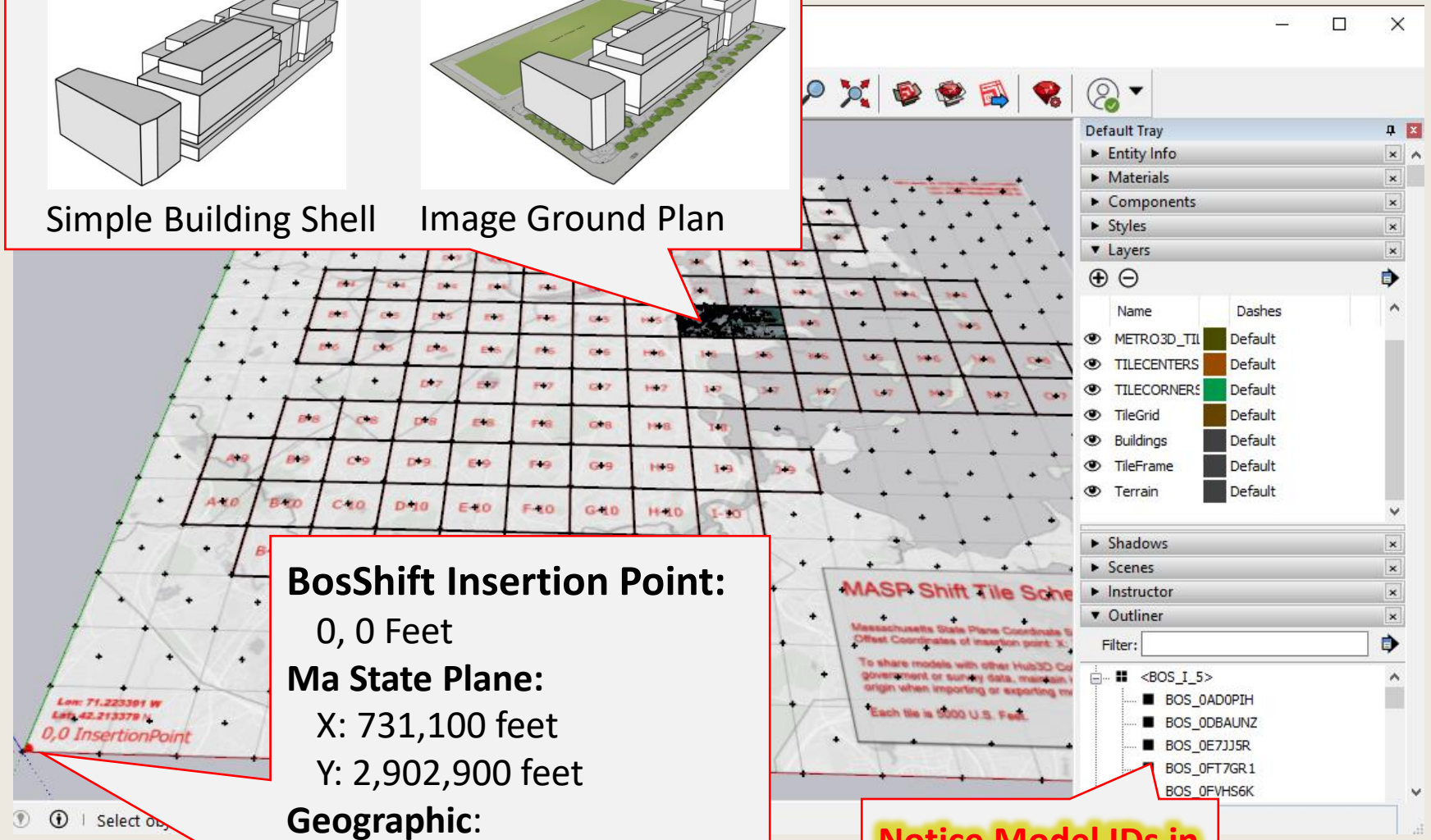


Image Ground Plan



BosShift Insertion Point:
0, 0 Feet
Ma State Plane:
X: 731,100 feet
Y: 2,902,900 feet
Geographic:
Longitude: 71.223391 E
Latitude: 42.213379 N

Notice Model IDs in Sketchup Outliner!

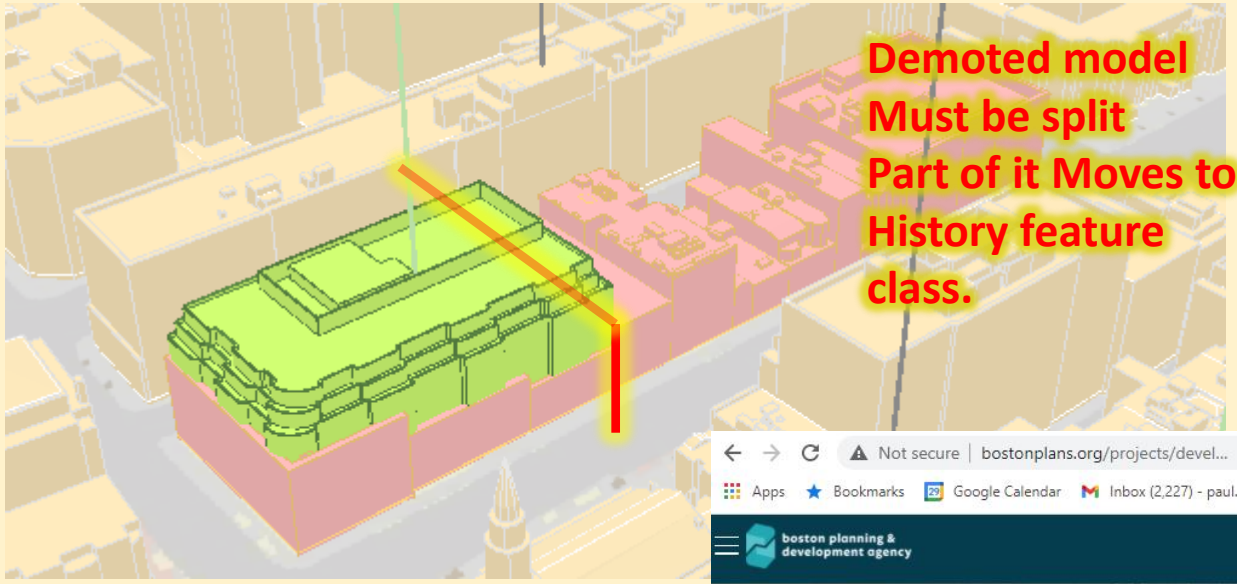
Model Collection Change Patterns

Changes to the 3D model Collection

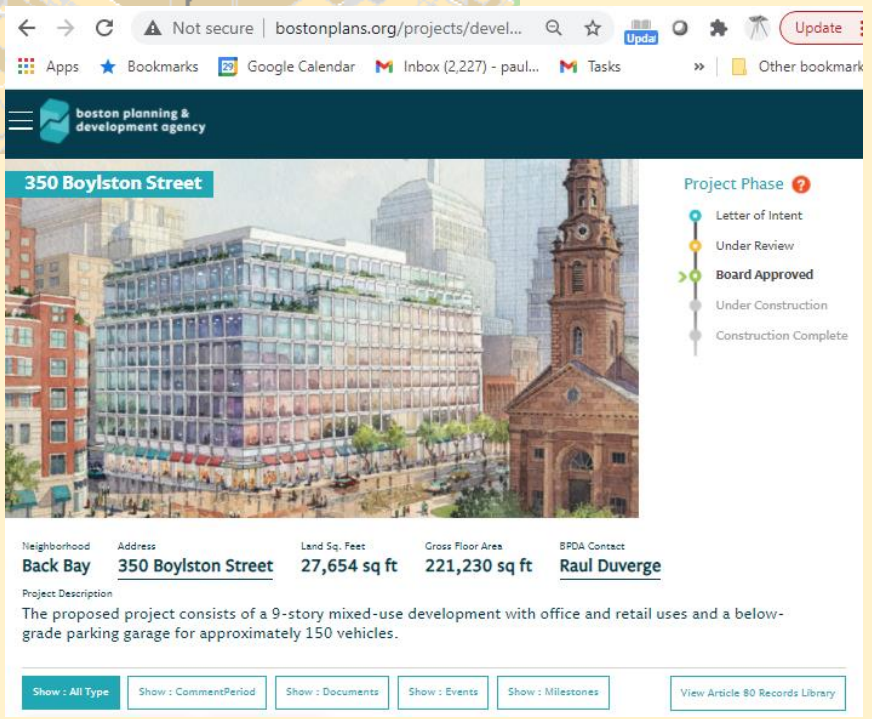
- New models are contributed to represent proposed structures.
- These may be developed in-house or submitted by developers.
- Models of proposed projects may get Status promotion
- Active models may get Status Demotion as they are Demolished
- Modified to accommodate new or promoted models, or just to fix something.

Boston's Article 80 process provides a database of projects which is updated to track any project through the approval and permitting process.

Large projects have a nifty public-facing web-page that links to all critical documentation. This link can be automatically constructed using the Project Name (in most cases.)



Import Model
or
Promote Status



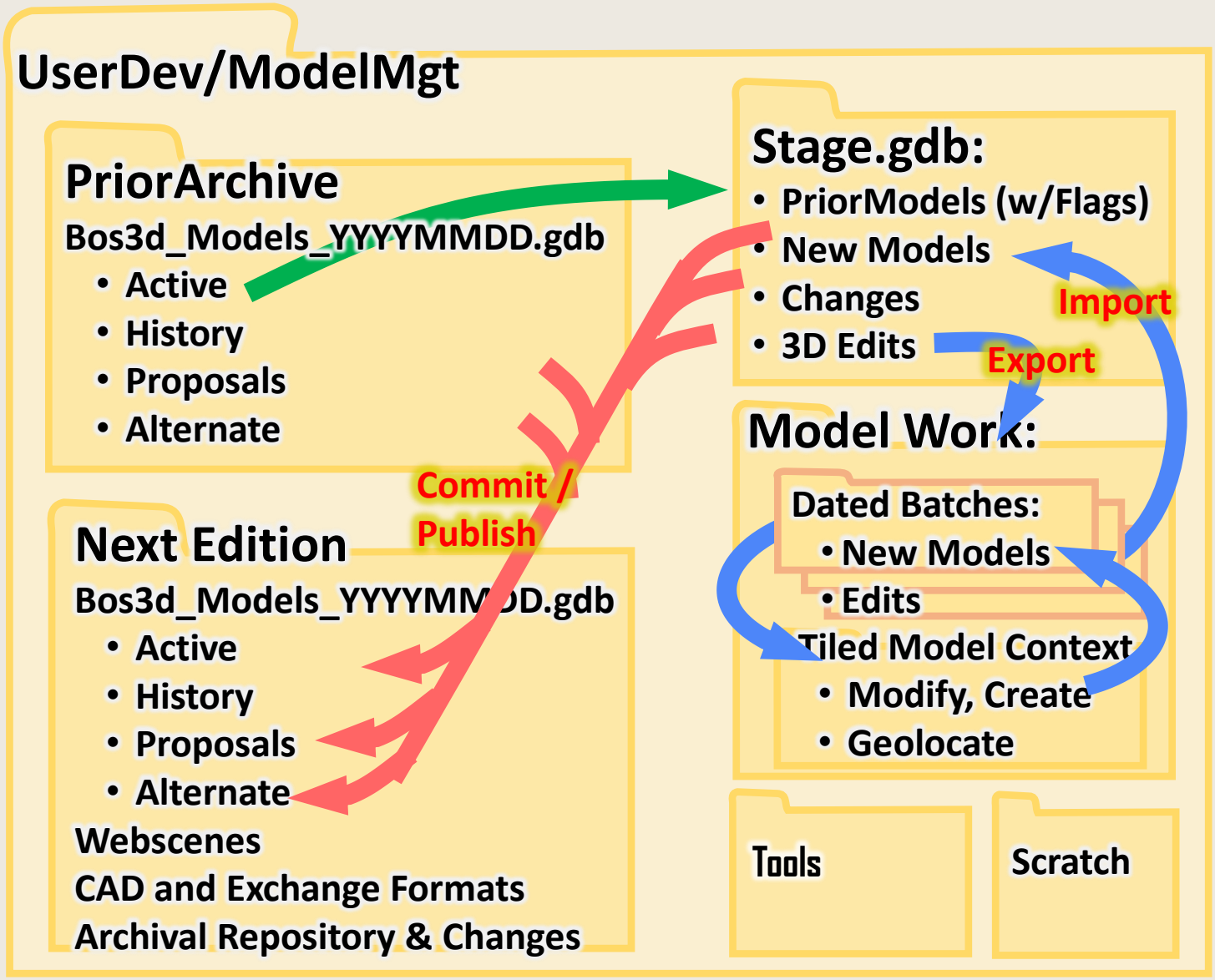
Managing the Collection of Building Models

Trying to use ad-hoc copy and paste to manage changes is a recipe for technical/emotional disaster.

- A person can spend a lot of time trying to decide where to put things or where to find things.
- Ultimately corruption happens
- Models or bunches of models end up missing or corrupted.
- The problem with missing data, is that you often don't discover that it is missing until a long-time hence.
- Much time can be spent trying to figure out which models are missing, and how to recover them.
- Ultimately you want to know where you can find the original source files for each model.

Experience has shown that it is best to manage these changes using patterns for Long Transactions

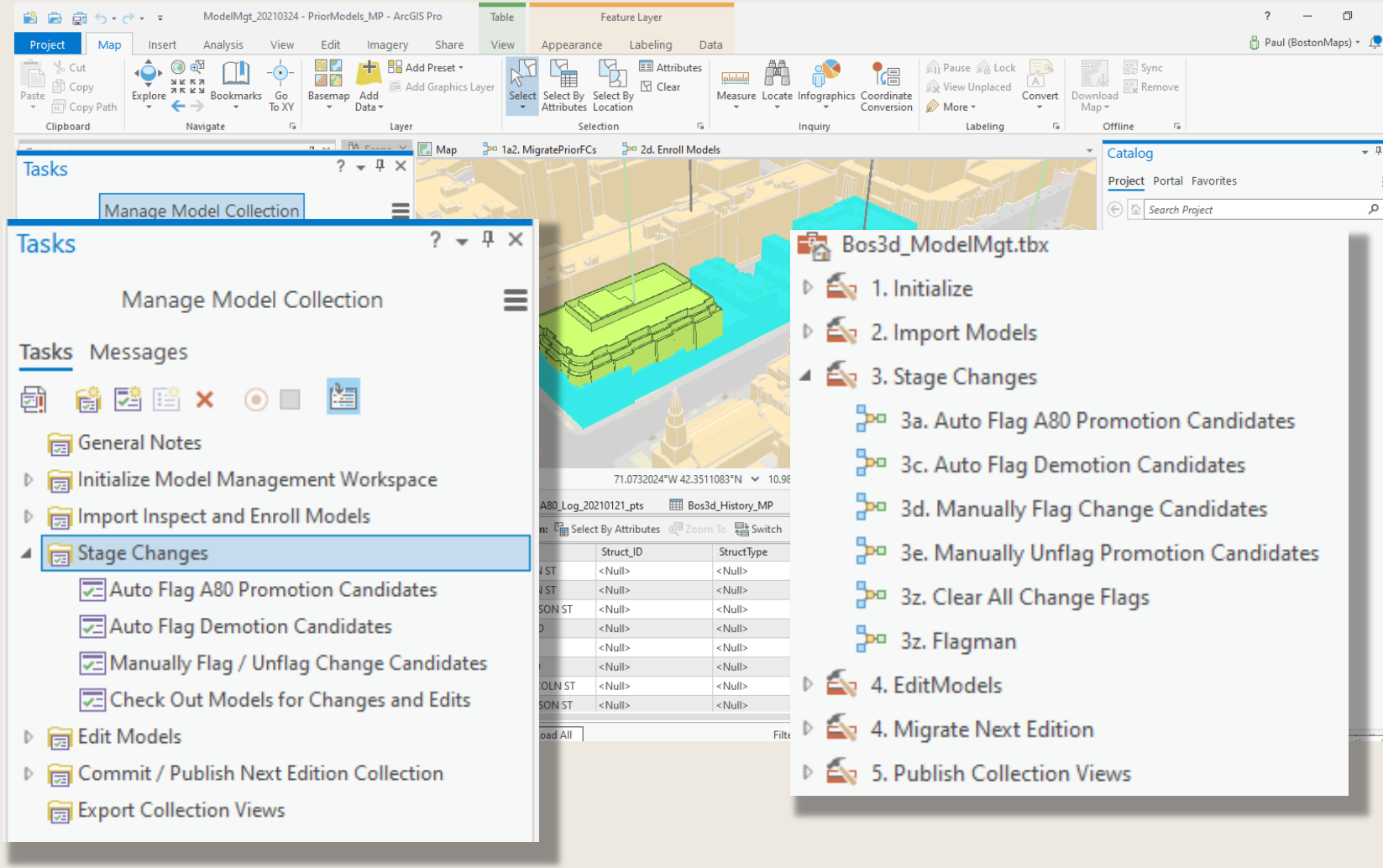
- A thoroughly planned file-system for filing and referencing source data – which is expected and enforced by tools.
- Capability of tracking and rolling back changes that is not limited



ArcGIS Pro Model Collection Management Tasks

- The model management workspace is a self-contained collection of tools and source material for investigating, staging and committing changes to the model collection.
- Adding new models calls for changing the status and dates of existing models
- Some models need to be edited with 3D modeling tools to accommodate changes.
- The model collection update process benefits from a phased strategy of Import, Staging, Verification, Adjustment, and Committing changes to the next version of the collection.
- This is a workflow that benefits from a carefully designed data model with a set of tools designed to ensure an audit and roll-back capability
- Because of the way that models can conceal each other, it helps to have a ready-made schema for styled definition queries to facilitate flashing change candidates.

The Tasks capability in ArcGIS Pro provides a framework for ordering and documenting the sequences of steps involved in staging and publishing changes in a safe, reversable way.



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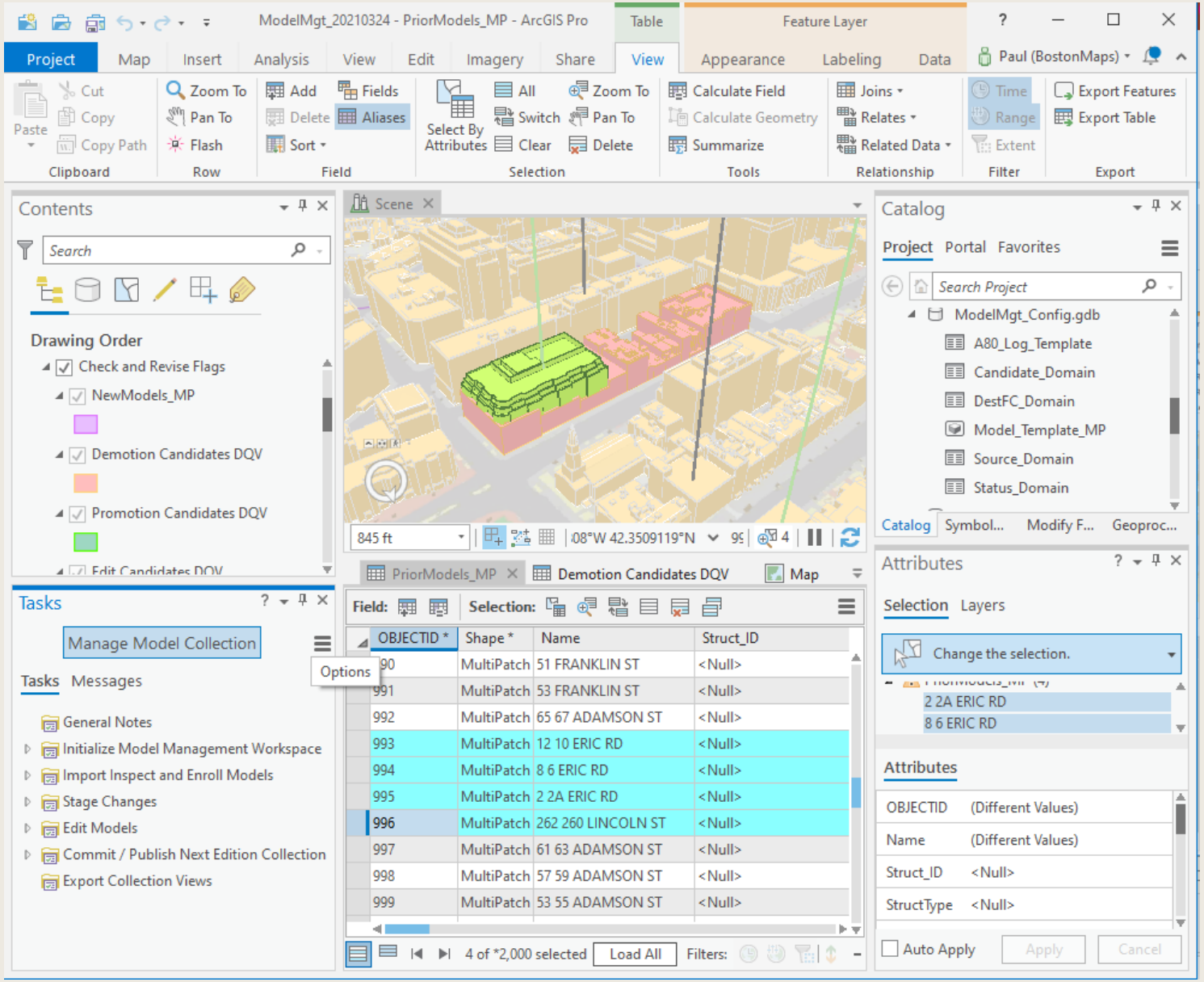


File System for Shared Resources and Model Development

There is a lot to keep track of during the model collection update process!

Much time can be wasted wondering where to store or where to find source material, and the products of various processes.

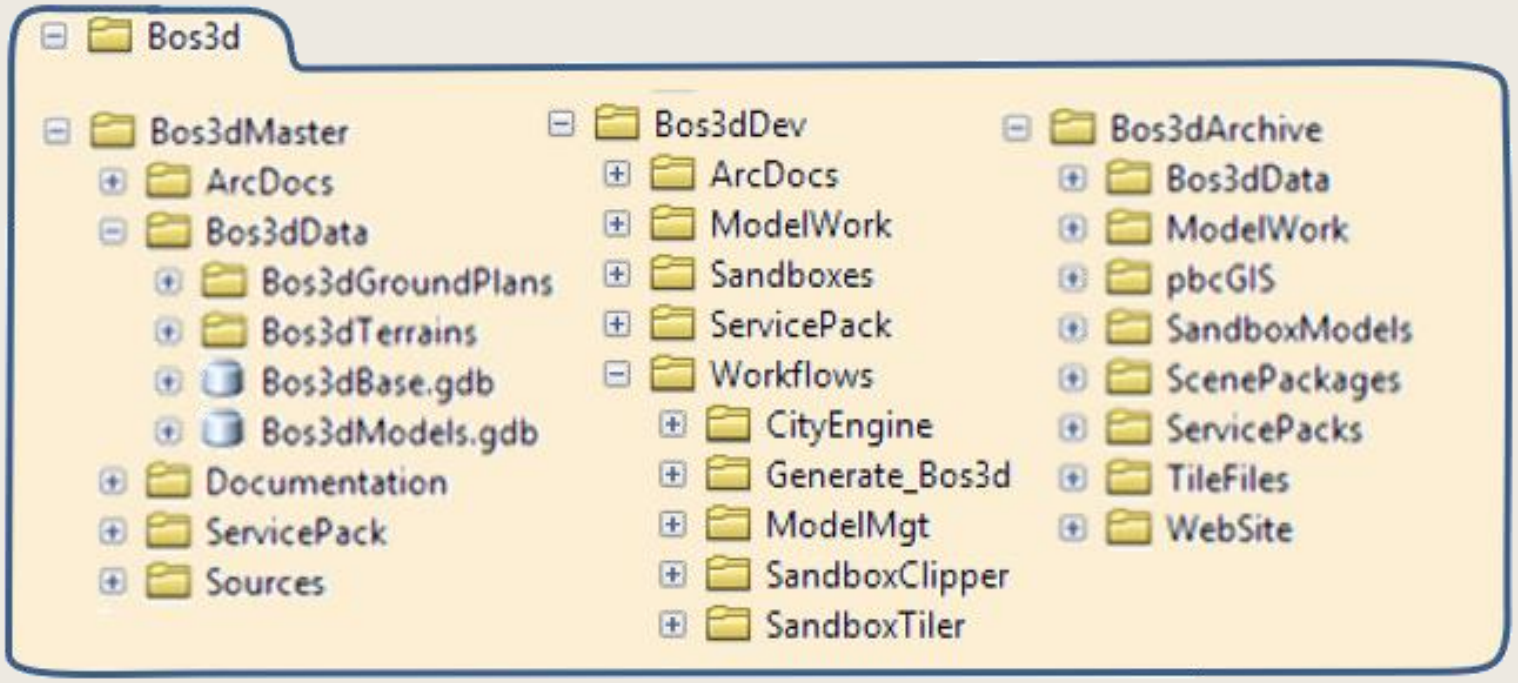
For quality control, it is very important to retain the original source material for models. We use dated model batches, which are referenced in the attributes for each multipatch.

The schema is designed to provide a scalable file management architecture that stays simple as it grows in the number of transactions or contributors.

The model management workspace is a self-contained collection of tools and source material for investigating, staging and committing changes to the model collection. All tools and critical sources are referenced within the workspace folder.

Workspaces can be used to manage all changes between one edition of the collection and the next. When a new update cycle is started, the ModelMgt workspace can be forked.

It is critical that custodians of the model follow a well-documented filing system if there is to be any hope of continuity of this project.



We will be publishing a full demo version of this project as a git repository when we prepare our training documentation.

The Model Collection is a Precious Cultural Resource

3D Models are Extremely valuable documents for understanding

- the history of places
- The History of Ideas about places
- As a context for understanding the relationships among other historical documents

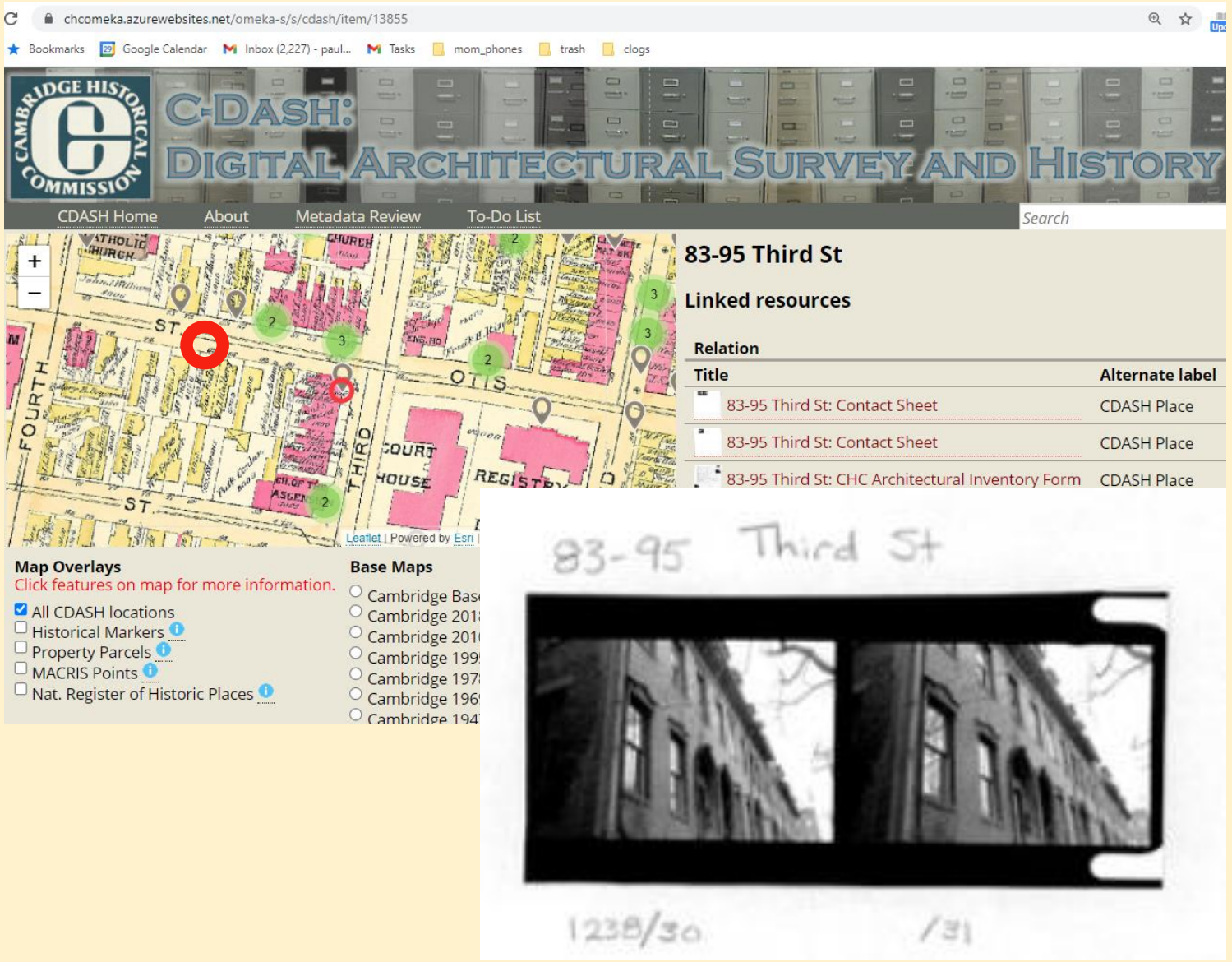
A library-grade preservation and re-use strategy

- Increases the value of the endeavor
- Introduces important ideas about the resilience and linkability of 3D model assets.

Users of Archival Systems are also potential contributors

- Modeling historical situations
- Deepening the attributes / knowledge about buildings and places

To develop a 3D city model without a strategy for very long-term preservation and re-use would be a REGRETTABLE and COSTLY missed opportunity.



3D Models Are a Historical Resource Multiplier

We all agree that 2D historic maps are very useful for understanding the context of

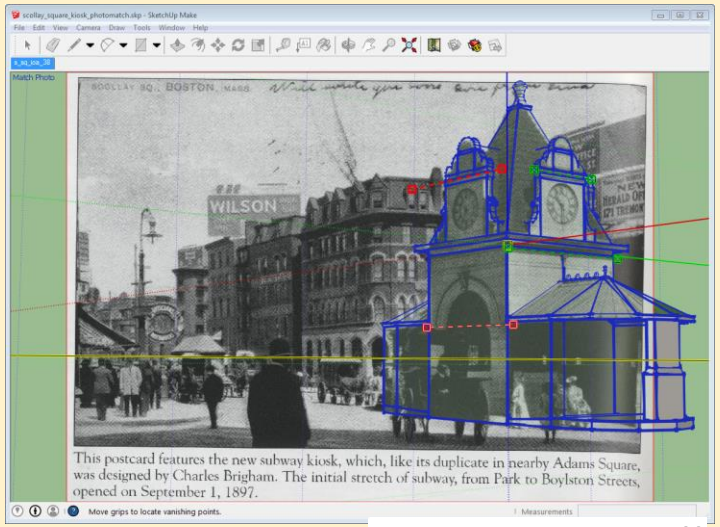
- Photographs
- Documents
- Plans
- Stories

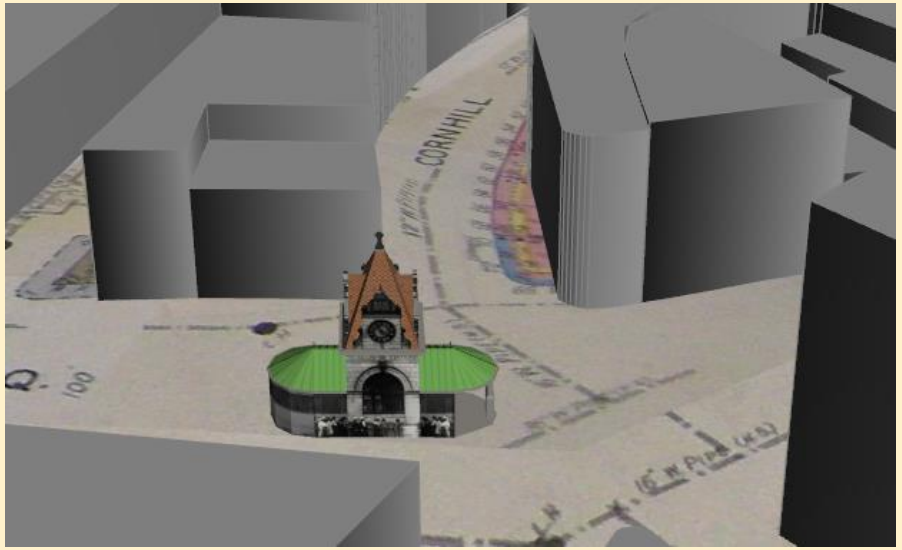
An interesting thing happens when rou georeferenced photos in 3D

- Puts you behind the viewfinder
- Photos become a reference for improving the 3D context Model
- Valuable new information is discovered about relationships of the elements in separate photos.

This demonstration is created with Google Earth. Download the KMZ at

www.pbcGIS.com/boston3d

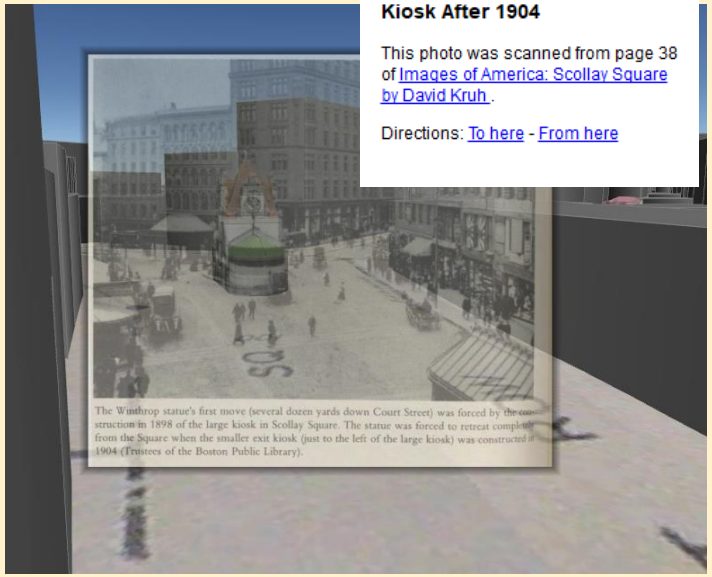


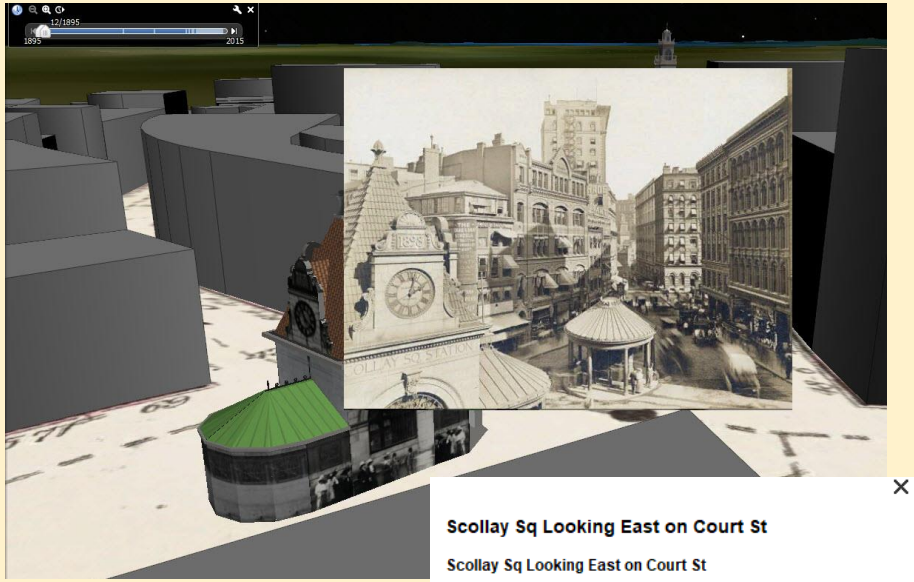


Kiosk After 1904

This photo was scanned from page 38 of Images of America: Scollay Square by David Kruh .

Directions: To here - From here





Scollay Sq Looking East on Court St

Scollay Sq Looking East on Court St

Downloaded in March 2011 from The Mideaeval Boston blog on Cyburbia.On a blog page by a cyburbia user known as Ablarc.

The caption is as follows:

Conclusion, Q&A and Resources

We hope that the resources we are developing in this project are generally useful to a variety of municipalities, campuses, design firms and cultural preservation archives.

Check www.pbcGIS.com/boston3d for updated resources including

- This slideshow.
- The Model Schema and Data Dictionary.
- A template geodatabase feature class.
- Eventually a link to the GIT repository that includes a complete demo collection with all of the tools.