Preserving the Bell Towers of Venice

Bells 2019

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Preserving the Bell Towers of Venice

An Interactive Qualifying Project
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Abstract

Our project seeks to aid in the preservation of Venetian bells and towers. Through detailed quantitative surveys of bell towers, and the creation of interactive virtual tours, we expanded the Venice Project Center's knowledge on bells and towers in Venice. To provide a comprehensive presentation of bell tower data, we redesigned the Bells Web App using new visualization techniques with improved data management and input technologies.

Acknowledgements

This project would not have been possible without the help of many collaborators, and we would therefore like to recognize those who have contributed to its success. Firstly, we would like to thank the professors who guided us through the development of our project and who worked to help us complete it. Our advisors Professors Fabio Carrera and William Michalson were essential in helping us complete this project during both the PQP and IQP processes. Additionally, Professor Melissa Butler's assistance during ID2050 was also greatly beneficial. Without their guidance in our research, writing, and presentation, we would not have achieved such a high quality of work.

At the Venice Project Center, we are thankful for the help of Piero Toffolo, Marco Bertoldi, Sarah Puccio, and Nicola Musolino. We are very grateful to Piero and Marco, who accompanied us to every bell tower we visited to ensure that each visit went smoothly. This included assisting us with data collection, warning us of potential hazards, translating bell inscriptions for us, and communicating with the local priests and groundskeepers. Sarah was also an essential part of the tower visitation process, as she coordinated with the pastors to schedule visits for us; without her, we would not have been able to visit as many towers as we did. We are also thankful to Nicola for guiding us in the recreation of the Bells App and integration with the VPC's database.

Finally, we would like to thank the past bells and bell towers teams of the Venice Project Center for providing a solid foundation on which to base our work. Our project is a continuation of twenty seven years of bell and bell tower documentation, and we realize that our work is most impactful only when placed in the context of the entirety of the VPC's bell tower studies.

Authorship

This report was outlined throughout many of the early weeks of the project. A large portion of this early work was done by Connor Bruneau, with occasional assistance from the rest of the team. Once all relevant data had been collected Connor and Isabel Bowman primarily worked on the final draft of the report, writing sections both individually and together. Ian Casciola also helped during this process by adding additional sections to the report, as well as helping to revise. During this time the overall organization of the report changed several times, with team members often reordering and rewriting entire pages. As such no author can claim ownership of any one section of the final version of the report. Finally all four team members were assisted during the final revision process by Matt Adiletta, who primarily worked on the revision of the bell tower database and web application.

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Preserving the Bell Towers of Venice

In Venice, Italy, there are one-hundred and thirty-six bell towers. They are used to mark the time, call Catholic worshipers to mass, and as points of navigation. Despite these purposes, the bell towers are losing their importance in the city, and are now perceived as a nuisance by the local residents. This is leading to a lack of maintenance by church officials that oversee the bell towers, resulting in bell towers that are unsafe and possibly at risk of collapse, posing a danger to the entire city and its residents (Lamorena, 2017).

The preservation of these towers and bells in Venice is important for three main reasons: cultural importance, practical purposes, and safety.

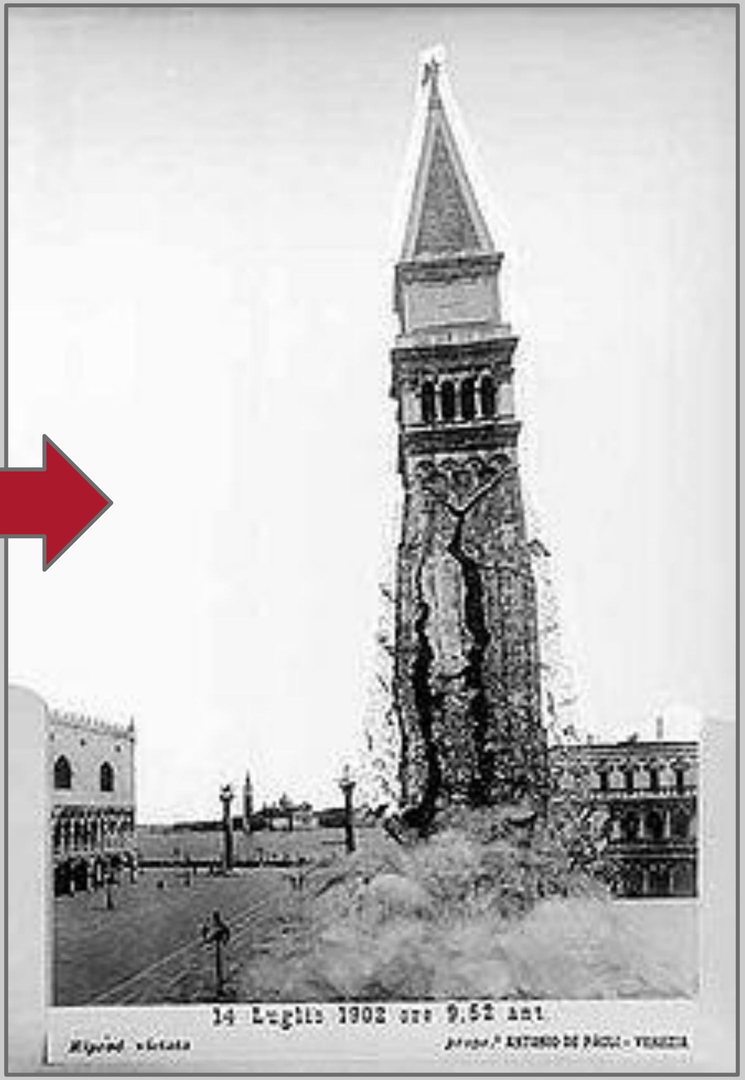
The Bells Towers of Venice: Cultural Importance

The cultural significance of bell towers in Venice is seen through their historical importance, artistic value, and religious connection. The historical aspect of these towers goes back to their constructions, ranging from the 14th, to the 18th century, allowing a glimpse into the world of the past. The artistic pieces of these buildings is seen in their architecture, their overall design, and the inscriptions and decorations that survive to this day. In modern society, the towers help to connect the people of the city to their religion, bringing the community together.

The Bells Towers of Venice: Practical Uses

There are three main practical purposes for preserving bell towers; maintaining functionality of the towers, repurposing the towers. Bell towers still server the practical purpose of telling time. The bell towers must be preserved for this reason. Bell towers rise above the city and can be reused for anything requiring higher vantage points such as cell towers, or aqua alta sirens. The tower of San Pietro was repurposed with cell signal emitters to provide coverage to the eastern end of the Venetian Island. The tower of Sant'Elena was fitted with security cameras to watch a boating club's private dock.

The Bells Towers of Venice: Safety



Bell towers need maintenance so they are not at risk of collapse. If a tower collapses, it has the potential to cause damage to a large number of buildings, and hurt or kill any residents or pedestrians that happen to be in the area when it happens.

An example of this is the San Marco collapse of 1902, where the largest tower in the city of Venice collapsed after cracks were observed on its foundation. Luckily, in this collapse only a single death was recorded, that of the groundskeeper's cat. If this tower were to collapse today, hundreds of tourists would be at risk.

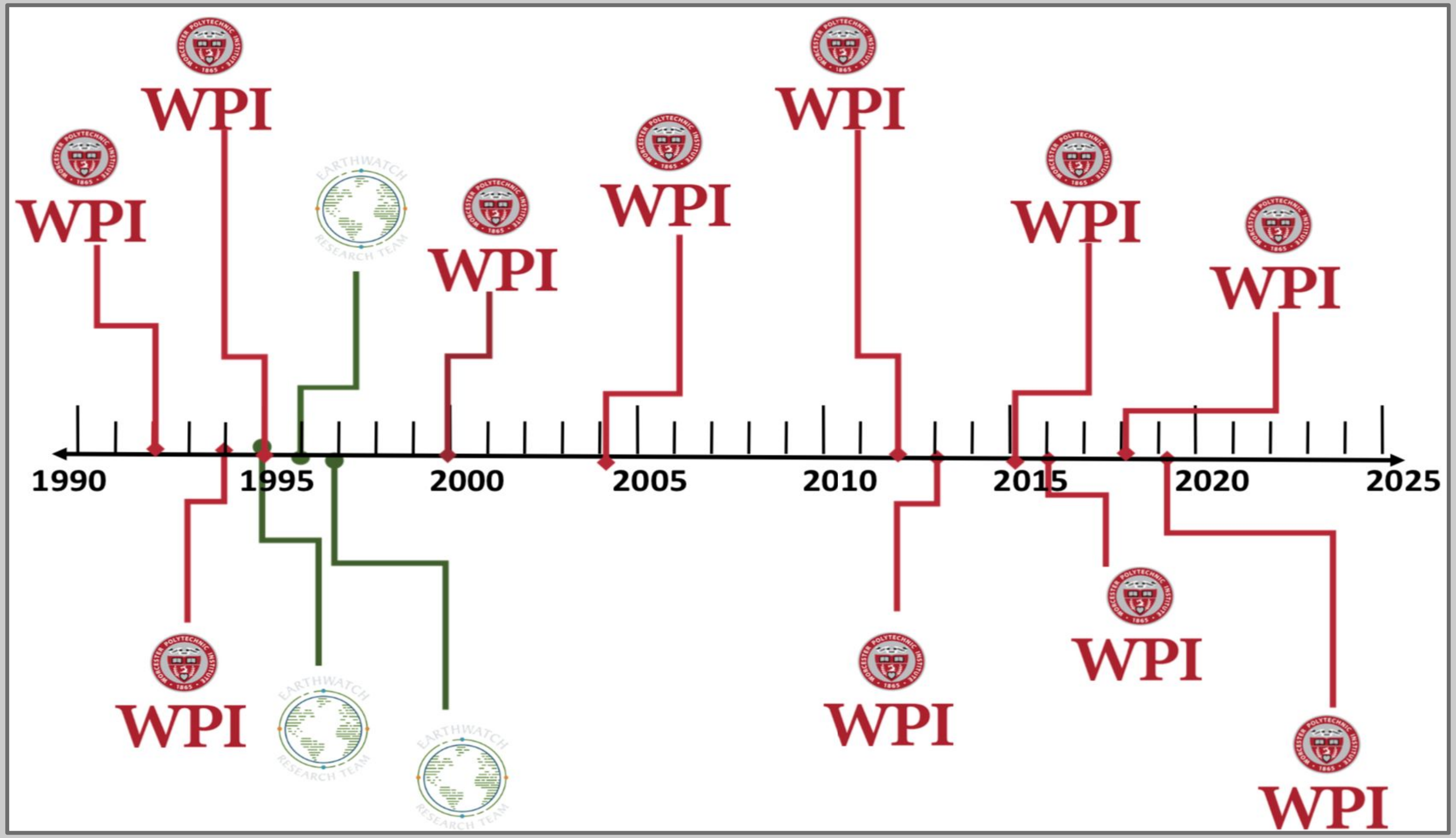

The Venice Project Center

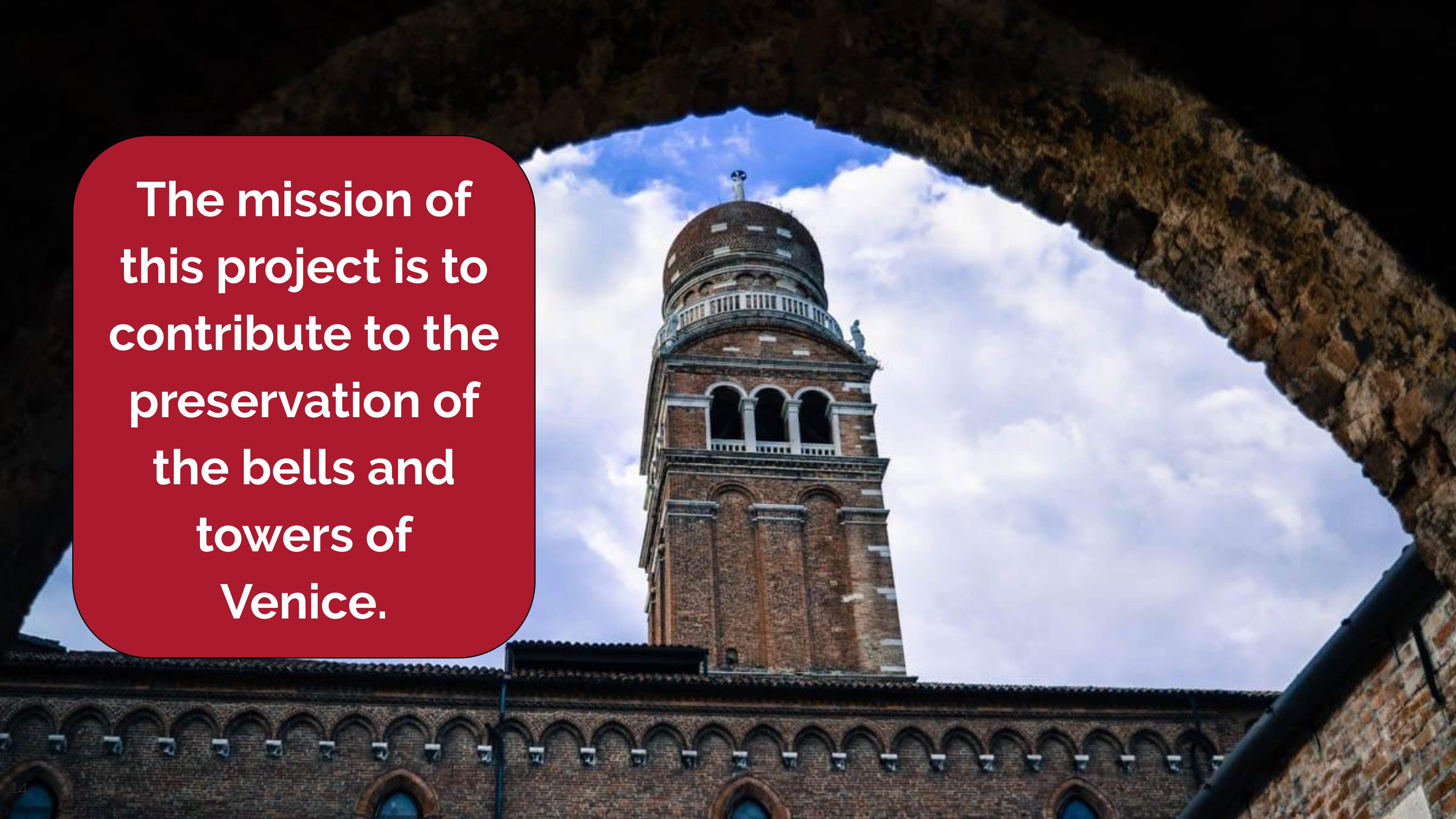
The Bell Tower Project

Over the last twenty-seven years, the Venice Project Center (VPC) has been conducting research with a goal to document bells and bell towers across Venice. Previous research teams have accomplished this goal by: recording observable data for each of the bell towers, creating an interactive online application to display bell tower information, capturing audio and visual collections via camera technologies, reporting information on dangerous bell towers to church officials, and investigating the structural integrity of the bell towers.

The Bells Project Timeline

Since **1992**, 11 WPI groups and 3 Earthwatch groups collected data on the bell towers of Venice.





The mission of this project is to contribute to the preservation of the bells and towers of Venice.

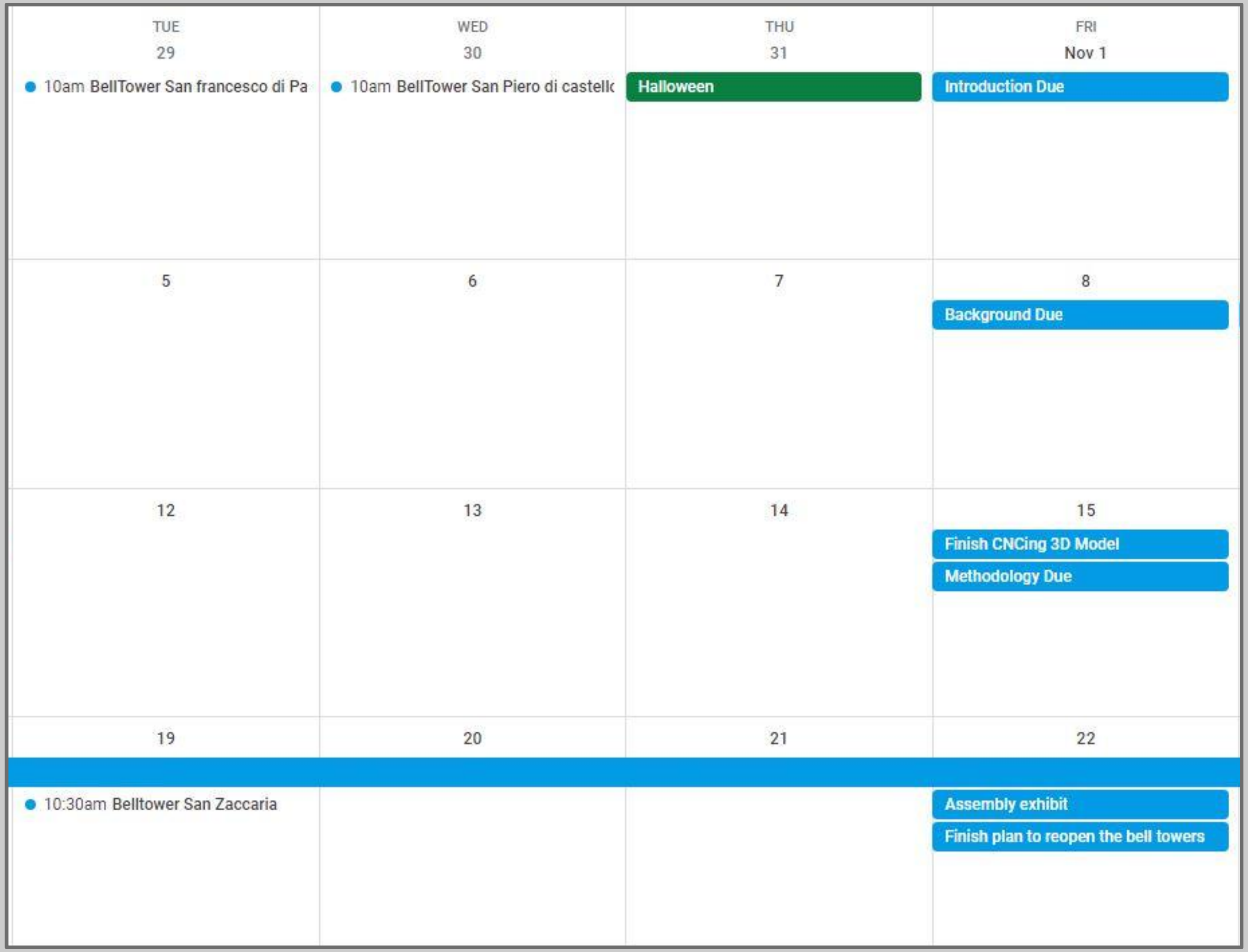
Objectives

1. To **gather data** about the bell towers
2. To **create engaging visualizations** of the bell towers and their conditions
3. To **publish collected data** online to the Bells Application

Gathering Data

Visiting Towers

Visits to bell towers are scheduled during the early weeks of the project. These appointments are handled by members of the VPC, who speak with local priests and groundskeepers about visiting individual churches and towers. Ideally, we are granted access into the the towers and their belfries to document and record data. If we are not allowed into the bell tower, we can only collect data on the exterior of the bell tower.



Arrival

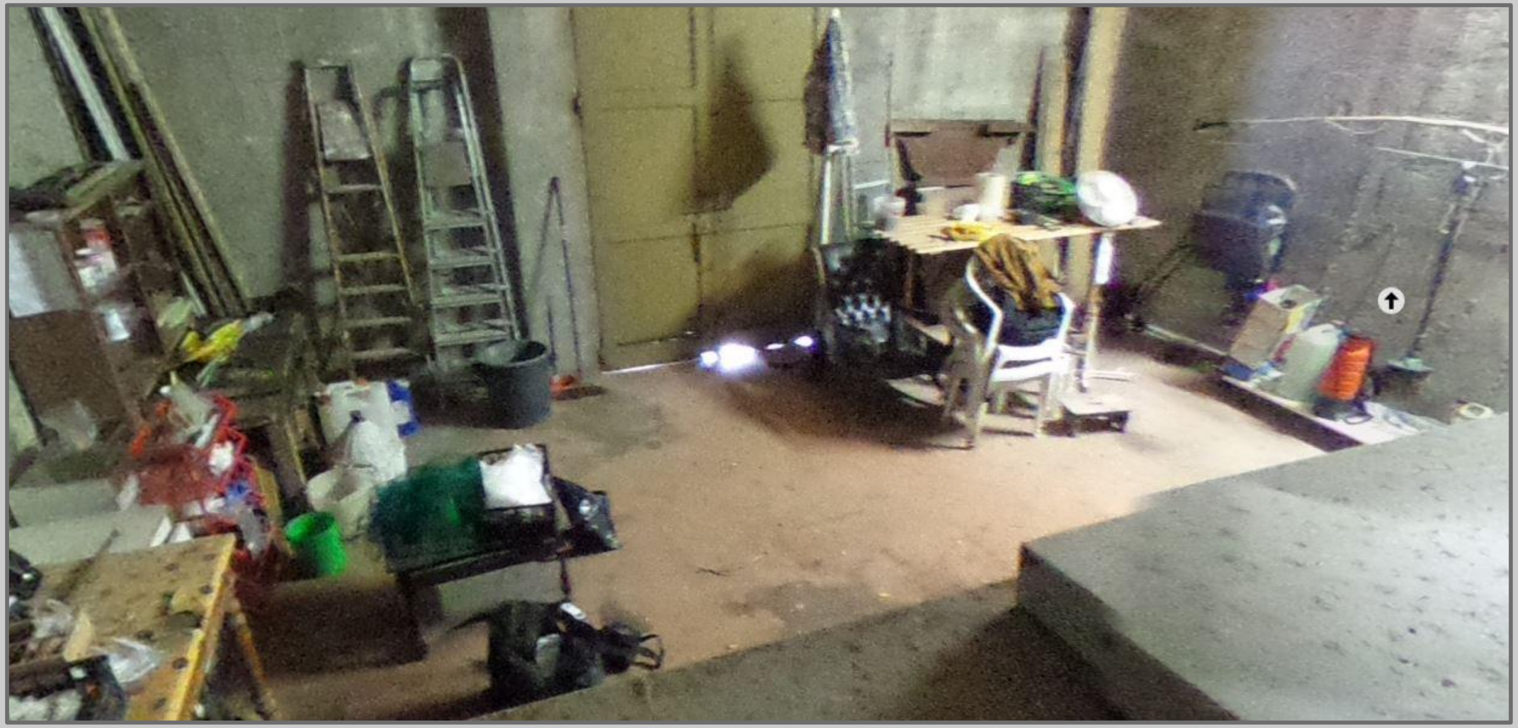
Trips to the bell towers are scheduled early in the day, typically around 10:00 am. On the morning of a visit, teams gather outside the tower or inside its adjacent church. A representative from the VPC arrives to assist us in gaining access to the tower. Together we meet with the priest or groundskeeper, and after a short greeting, our team is taken to the ground floor of the tower. This official may choose to accompany us up the bell tower, however, more often than not, we are allowed to freely tour the tower.

Arrival - Exterior

Prior to making our way inside, the team is able to document the exterior and the surrounding area of the bell tower. While some towers are free standing, most are connected to their respective churches and several other buildings such as schools and hospitals. Additionally, a few of the towers we visit have notable inclinations, with some towers visibly swaying as their bells ring.

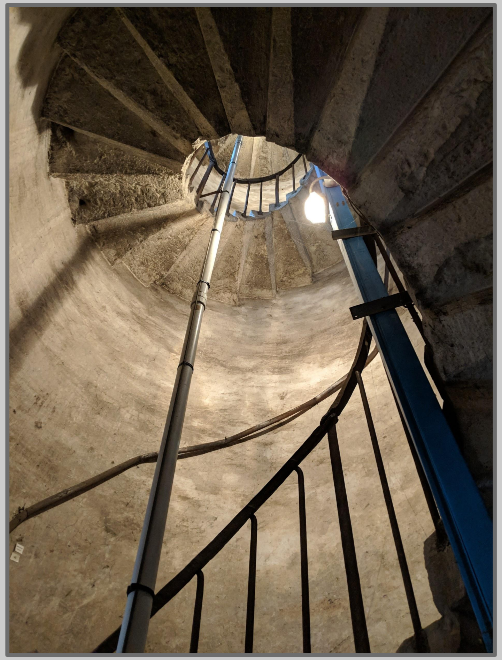
Arrival - Ground Floor

Upon gaining access to a bell tower, we first enter from the ground floor. For bell towers that are connected to their churches, these entrances are usually used as storage rooms or small offices. As such, the ground floor is typically in much better condition than the rest of the tower. The ground floor also has the mechanism the priests use for scheduling the ringing of the bells. Occasionally these devices are kept in a room adjacent to the tower itself.



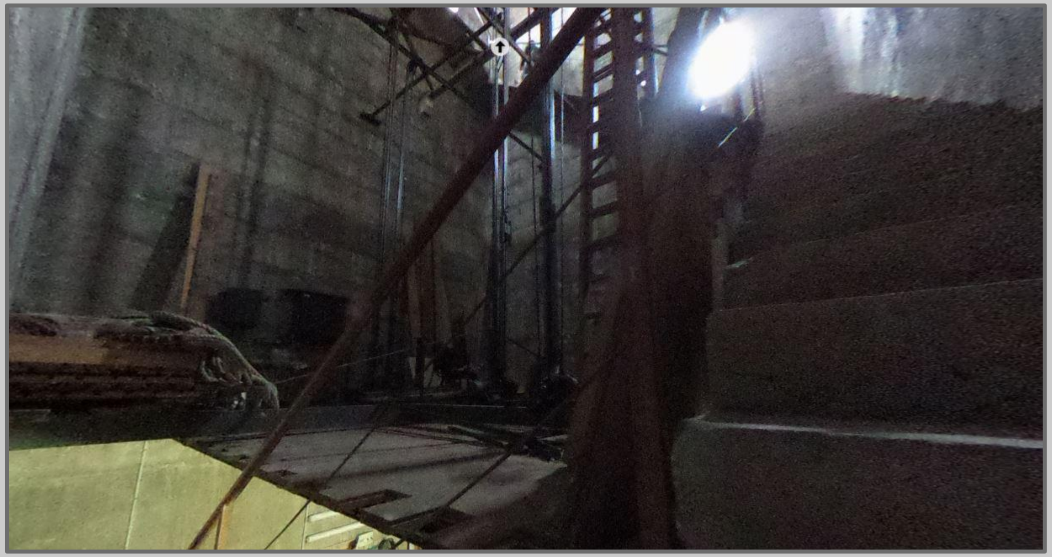
Arrival - Stairs

After arriving at the ground floor, we begin ascending the bell tower. The VPC takes note of the different types of stairways. These could be traditional staircases that only ascend in a single direction or spiral staircases that covered large portions of the shaft. Often, older towers have their original stone steps and ramps which makes the traverse difficult. Sometimes towers have wooden steps, which are typically in poor condition from either a structural or cleanliness standpoint. Newer towers that see frequent use often have updated metal staircases or maintained stone or cement staircases.



Arrival - Landing

The next major stop during our assent of a bell tower are the individual landings. While some towers simply have a ground floor and a belfry, many have multiple floors. These vary greatly in size, with some only being a few feet across, while others are the same size as the belfry itself. These landings can have doors to balconies, side rooms for storage, or even access to the attic above the church.



The landings of the bell towers throughout Venice are used for a variety of purposes. While some landings are empty, others house mechanisms for ringing the bells or even operating an elevator shaft. Some churches also utilized the landings as storage, for either files or religious paintings and artifacts.

Arrival - Belfry

The final stop during our bell tower tour is the belfry. Upon entry to the belfry, we encounter the frames and bells of the tower. There are two major types of frame to hold up the bells, either H-frame or A-frame. These frames are made of either metal or wood or in some cases a combination of metal and wood. Occasionally, bell towers will not have any bells, while other towers have as many as seven. Some towers even have a sonello - a smaller bell not hung with the other bells. Sizes of the belfry also vary with tower size, and the amount of free space inside is heavily dependent on the number of bells.

Each belfry has large windows on each of its four sides. If a tower is not very tall, bird netting is likely installed, made of a metal wire mesh. Some towers also have an attic above the belfry. Attics are typically not accessible.

Gathering Data at the Towers

Upon gaining access to the towers, our team splits up to efficiently collect data and images. One team member starts outside the tower to document the exterior features of the tower, while another member remains inside the tower to document the interior features. A third member begin documenting the belfry and the bells, while the last team member collects images and video recordings of the tower using various types of cameras.

If one team member finishes their portion of the documentation early, they would typically assist other team members in collecting data. This ensured that all data points can be recorded in a quick and efficient manner, with the entire data collection process typically only taking around two hours, including time spent waiting for bells to ring.

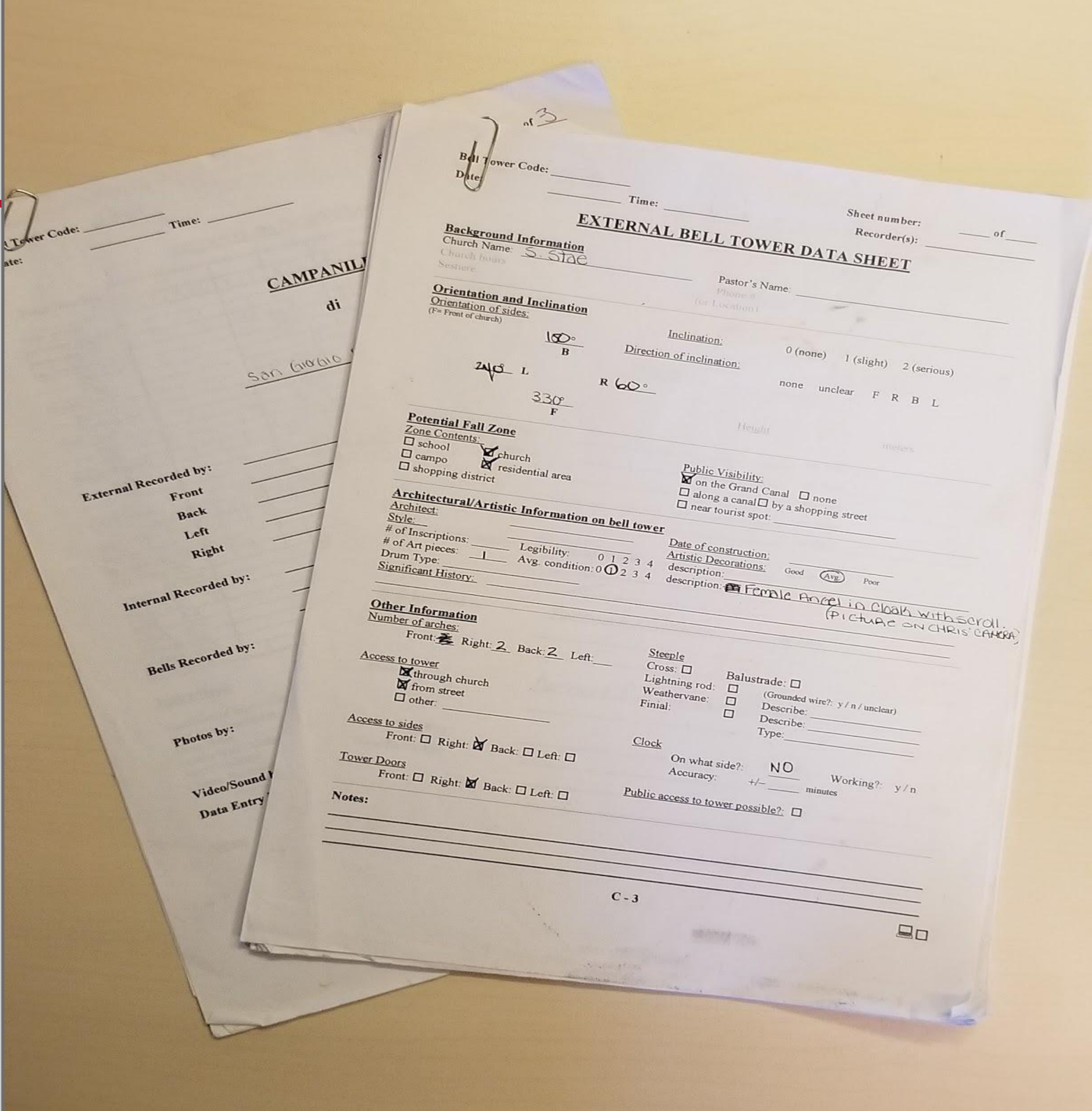
Bell teams collect over 300 data points for each tower. A full list of the data fields can be found in Appendix A. In order to keep track of collected data during tower visits, data sheets are used which have been developed by teams over the last twenty seven years.

Recording the Data

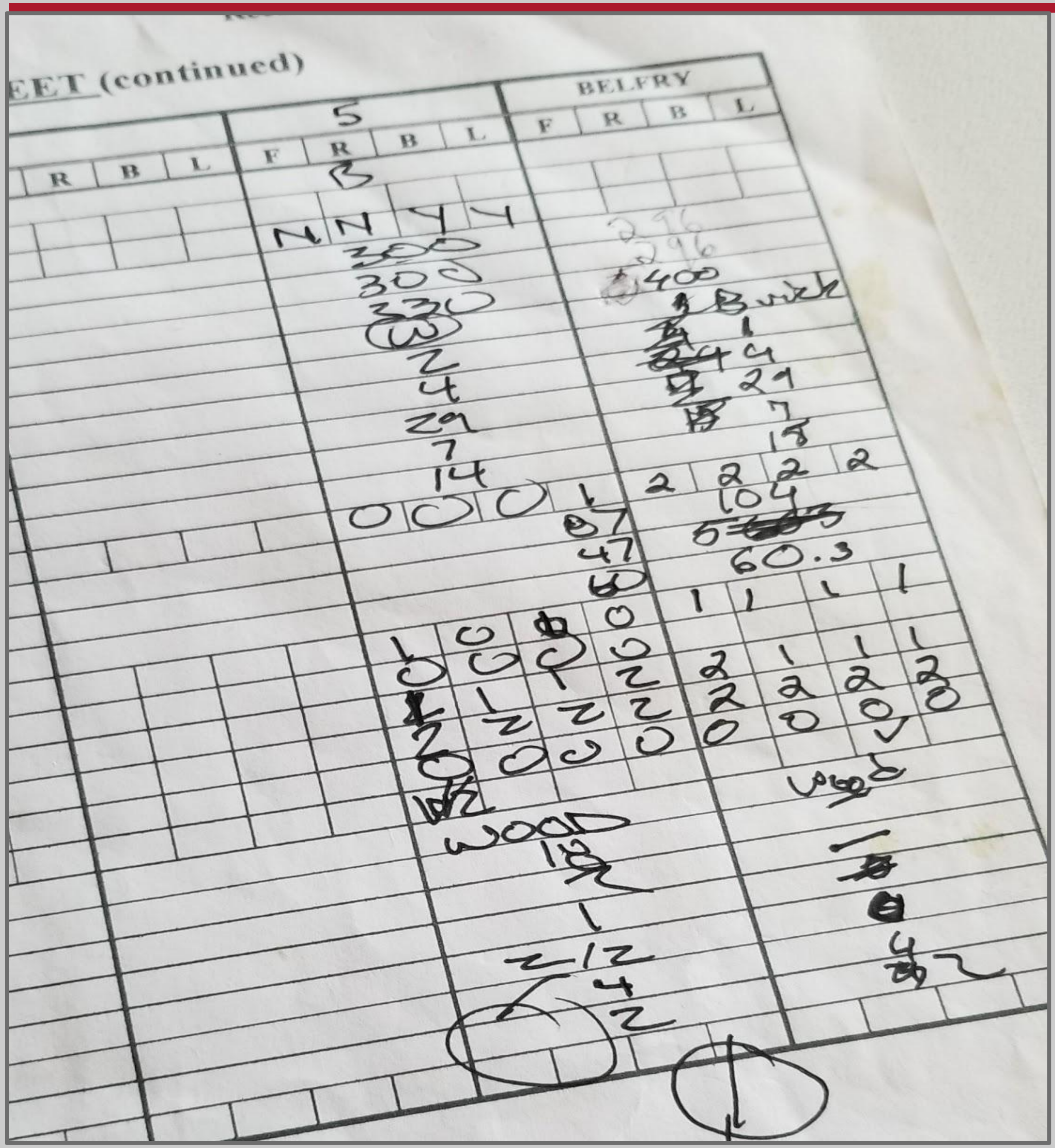
The first step for recording data about the bell towers of Venice is the collection of quantitative and qualitative data on the interior, exterior, and bells of the the towers. To do this, early bell teams establish their own set of data fields to collect during visits to the towers. Quantitative data includes landing dimensions and number of windows, typically measured in centimeters or meters, or simply counted.

Qualitative data is focused on areas such as sturdiness and cleanliness, recorded on a scale of 0 to 4, with 0 being the best possible condition and 4 being the worst. The original form of documentation used paper forms, filled out at the tower. Upon arriving at the towers, teams can speak with the priest or groundskeeper, asking questions about the tower and its history.

Collected data is recorded on the paper forms to be stored for later use in the project. Additionally, these forms are used as guides for future teams, giving them an idea as to what types of data should be collected and how to capture that data.



Recording the Data - Analog



Unfortunately, this method of collecting data proved to be inefficient when applied over multiple years . While the paper forms allowed teams to keep track of their findings amongst themselves, the handwriting is not always legible, leading to data being lost. This makes it difficult for teams to reference previous findings. Additionally, individual pages are sometimes damaged or forgotten during visits, creating disorganization.

The greater problem with the way in which previous teams recorded data is the lack of consistency among their collected fields. Some teams neglected certain fields during their visits while others recorded the data electronically and failed to utilize paper forms. Due to this lack of coordination, the data displayed for each bell tower on the VPC's website is inconsistent from entry to entry. Some towers have data fields that are unclear or incomplete, while others have vastly more information.

In order for the project to be more successful for future teams, the data collection process needs to be both streamlined and standardized. This way, each bell tower entry in the database is consistent and useful for visitors to the VPC's website.

Recording the Data - Digital

To help improve the data collection process for current and future teams, we created a variation on the original collection method. Instead of utilizing paper forms for recording data, we created a spreadsheet with different pages for general information, exterior data, interior data, and bell data. The data fields on the sheet are derived from a variety of previous forms to encompass all data that is recorded for each part of the tower. These spreadsheets are accessible and editable by each team member on their cell phones during visits to the towers. With this electronic method, legibility is no longer an issue, and fields are easily edited if a mistake needs to be corrected. Additionally, copies of the files are saved in multiple location to reliably preserve the data.

Floor								
Basic Landing Info	Ground (0)	Belfry	Landing 1	Landing 2	Landing 3	Landing 4	Landing 5	<--- Add more landings if necessary
Landing_Material	concrete	concrete, brick	wood					Text Wood, Brick, Stone, C
Landing_Sturdiness	0	1	1					Rating 0 (best) to 4 (worst) Sturdiness of Landing
Landing_Cleanliness	1	1	2					Rating 0 (best) to 4 (worst) Overall cleanliness of landing
Landing_Length_cm	683	670	686					Number Length of landing in cm (Front to Back)
Landing_Width_cm	683	670	686					Number Width of landing in cm (Left to Right)
Landing_Height_cm	381	820	3290					Number Landing height in cm (floor to ceiling)
Natural_Lighting	4	0	4					Rating 0 (best) to 4 (nonexistent)
Artificial_Lighting	2	4	4					Rating 0 (best) to 4 (nonexistent)
Notes								Text

Gathering Exterior Data - Why, and the Past

The collection of exterior data is used to aid the team or church officials in assessing the overall condition of a tower. By recording the number of visible cracks, tie bands used to hold bricks together, restoration work completed, or degrees the tower is leaning, the total condition for any given tower can be assessed without having to enter the tower. Exterior data such as tower height, arches on the belfry, or finial type, are recorded for publication and possible distribution.

Before phone cameras and laser measuring devices, the methods teams used was analog. The early bells teams took pictures using a 35mm camera, recording the location the picture in a booklet. They later had to develop the film.

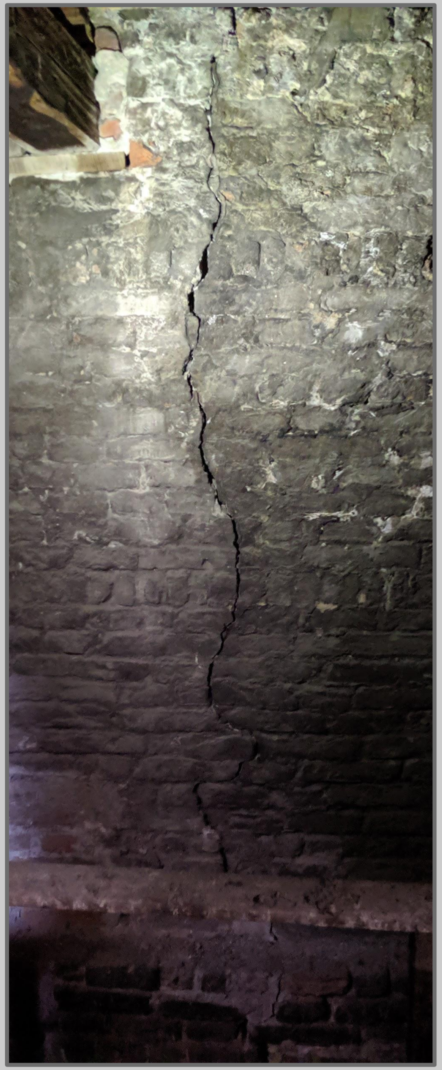
Large measurements such as the height of the tower had to be measured with less accurate methods. The first team found the height of a tower by taking a picture, finding something in the picture they knew the height of, and then roughly guessing the total height of the tower based on that scale.

Other data, such as the number of tie bands, cracks in the tower, and other physical properties of a tower were recorded simply by looking at the tower, and recording what they saw on the paper forms.

Gathering Interior Data: Why, and the Past

The collection of interior data allows for a comprehensive understanding of the condition of a tower. The inside of a tower contains landings, railings, tie bands, and other pieces that are important to the overall state of a tower. Landings can be unsafe, stairs damaged, and railings rust, so it important to record anything that may be dangerous so it can be fixed. Recording the interior is also important because the experience of being inside a Venetian bell tower is unique to church staff, and WPI Bells IQP students. As such, on top of the creation of digital visualizations of the interior, it is also necessary to document the specifics of the tower for anyone to look at, and analyze.

While technology has changed significantly since the beginning of the VPC, the methods for recording the interior of the tower have not. The largest change over the course of the project was that students before would use 30mm cameras, and measuring tapes, this year's team used phone cameras, and laser measuring devices.



Gathering Exterior Data - How, and Changes

To measure the tower height, we employ two methods utilizing the Spike measuring tool provided to us by Prof. Carrera. This device works in conjunction with a smartphone application to create point-to-point measurements on images taken with that phone. To get tower height, we measure the distance from the observer to the base of the tower, then the distance from the observer to the top of the tower. From here basic trigonometry is employed to calculate the height of the tower. We also use the laser measuring device on the interior of the tower to measure the height between landings as well as the height from the belfry floor to the roof. While we are not able to accurately measure to the top of the roof, this method does provide a good comparison to seeing if our earlier method provided reasonable results. Finally, after the height measurements are compared with one another to see if they are similar, they can be cross referenced with a data sheet from past projects, found at the VPC.

To measure the inclination and orientation of the towers, our team utilizes compass and level applications installed on our smartphones. These measurements are taken on all accessible sides of the tower in multiple locations. By placing the top of the phone against the wall we are able to record the resulting degrees and compass direction. Prior to this, the front side of the tower needed to be established for reference, and is designated as the side facing the same direction as the front of the church, which is the side opposite the church altar. In order to measure the inclination, we use the level against all of the walls in the tower in the base and shaft. Since the bricks making up the walls were not always level we were forced to average multiple readings together.

Gathering Interior Data: How, and Changes

The data on the interior of the towers was focused on the decoration and dimensions of the tower interior, the dimensions and condition of the stairs, walls, and windows, and the type and condition of the bell frame. We collected 87 different data fields based off of the data collected by the 2018 team. The interior of the tower was divided by the landings in the tower, including the ground and belfry. All qualitative measurements were made by direct inspection of the object or room in question. Condition measurements were documented with photographs. Physical measurements were made using a laser measuring device. Pictures of the internal features of the tower and its views were taken in the collection.

For quantitative interior data, our team collected the measurements of the landings traveling up the tower. Landings are defined as large, open areas that could contain more than one person at a time and were not simply larger steps in the staircases. Dimensions of the landings, stairs, doors, and windows were also recorded using the laser measuring device. In order to measure wall thickness we looked for a window without glass or a screen so that we could get the laser out to the edge. We could then measured from the inside of the tower wall to the surface outside the window. Similar to before, assessments of the lighting, sturdiness, and cleanliness of the stairs and landings were made on a scale of 0 to 4 with 0 being the best and 4 being the worst or nonexistent.

Gathering Bell Data - Why, and the Past

In addition to the collection of interior and exterior data, it is also vital to collect data on the bell. These bells are not only of great historic and artistic value, but also a feature of the towers that are in danger. If not properly maintained, these works of art can become irrevocably damaged. As a result it is crucial to gather data on them as well as visually document them so that they can be properly recorded and protected. Most towers are home to an entire chorus of bells, each with their own dimensions and sounds. Additionally, many of the bells contain inscriptions that needed to be recorded and translated.

Much like the interior and exterior data collection methods, the methodology for gathering data on the bells themselves has not evolved greatly over the years, with many of the same techniques originally used in 1992 being used almost three decades later.

Gathering Bell Data - How, and Changes

For the bells within the towers, our team focused on collecting the same data as previous projects collected. The first type of data we collected was about the ringing of the bells. Using an audio spectrum analysis app on a smartphone, we measured the ringing frequency of the main hum, then used the frequency to calculate the musical note that the bell played. We then recorded the sound of each bell by manually swinging the clapper. If the bells still were rung normally, we also recorded the bell chorus.

If the information was available, we also recorded the time of day the bells ring during the week. Next, we collected data on the artistic design of the bell. This consisted of describing the engravings on each side of the crown, body, and lip of the bell and taking pictures of all accessible sides of the bell. After describing the engravings, we recorded the inscriptions on each side of the crown, body, and lip of the bell. If the inscriptions were unreadable, we cleaned the bells with water and brushes, then used chalk to make the letters stand out. Whenever possible, we used the inscriptions to record the date that the bell was made and the foundry that cast it. We then recorded the length and condition of the clapper as well as the way it was attached to the bell. We continued by recording if the bell was still rung and the method with which it was rung. Finally, we recorded the physical properties of the bells. Diameter, internal height, and height off the ground were recorded using a tape measure. Calipers were used to measure the bell thickness. The calipers were placed at the intersection of the body and the lip of the bell, which is its thickest point, and were tightened as much as possible without scratching the surface of the bell.

The distance between the two claws was then measured with a tape measure. Next, we recorded which sides of the bell were cracked, if any. Finally, we recorded the cleanliness, discoloration, amount of chips, decoration legibility, and overall condition on a scale of 0-4, where 0 is very good and 4 is very poor.

Photography: Why, and the Past

In addition to qualitative and quantitative data, it is also important to visually document the towers through photos and videos. This allowed teams to not only capture the beautiful views from the belfries, but also document flaws and problems with the towers. For instance, stairs that were deteriorating were photographed to be recommended for repairs later. Originally, these photos were taken with a 35mm camera, the same as the exterior and interior data collection. Later, teams elected to use their phones to capture images, in an attempt to expedite the process. Finally, 360 degree cameras were used not only to capture a greater percentage of the towers, but to also allow teams to create panoramic photos and virtual tours of the towers.

Photography - How, and Changes

Victure Camera

Ricoh Theta V Camera

In 2019, the Victure camera was used to take videos walking up the stairs in the shaft of the bell tower to the belfry. These videos are uploaded to youtube and featured on the bells application to give the viewers a sense of what it looks like walking up a bell tower, seeing the structure, stairs, or any mechanism in the shaft to ring the bells in the belfry.

The camera is also used to record the way that the bell swings while it is ringing. The camera is placed on the ground directly under the clapper of the bell to capture a video the bell ringing. These videos are also uploaded to youtube and featured on the bells application so viewers can not only hear the bells ring, but see it as well.

The Ricoh Theta V camera was used to capture 360 degree photos from three major sections: the church, the stairways in the shaft, and the belfry. These images are used in virtual tours of the bell tower, also featured in the bells application.

We also take photos of the churches to give viewers the chance to embrace the beauty and culture within the church connected to the bell tower. The stairways give the viewer another visual along with the Victure video. The belfry is the most important section of the virtual tour. There are pictures of the bells, the ringing mechanisms, the frame type, the views and more. The tour allows the viewer to zoom in on details and move to different locations for different views.

Photography

Sant'Elena

Creating Engaging Visualizations

Why Visualizations?

Most of the bell towers in Venice are not open to the public; residents and tourists currently can see the exterior of the towers. Our team's goal is to be able to give anyone that views our application the "experience" of what the bell towers have to offer. In addition to raw data collected, we display photos and videos so that viewers can feel as though they are walking through the tower.

Panorama App

Photo Stitcher App is a great application available on smartphones that allows the user to take multiple pictures that can be stitched into one panoramic photo. Through trial and error, it became evident that the overall quality of the panorama turns out better when the user has a constant camera level throughout to ensure the horizon will be straight when the photos are stitched together. Overlaps between the photos taken are how the application is able to stitch the photos together, so it is best to have at least 25% of the previous photo to overlap into the new photo. If the photos are not overlapped enough or taken at a unlevel plane, the application will not stitch the photos together.

The application gives the user the option to take 3 horizontal (landscape) photos or 5 vertical (portrait) photos on the app or upload a personal smartphone library of photos. It is ultimately most efficient to take photos through the application while in the belfry, as they can be automatically stitched together then instantly ready to view and save. After multiple panoramas are created and saved to the user's personal camera roll, the panoramas can be selected from the library and stitched together to expand to one large panorama. It is also important to take an assortment of photos on the smartphones camera roll as backup photos after leaving the tower to use as needed.

Photo Stitcher App

Panoramic View from San Moise

Photography - Panorama Examples

360 Degree Photo App

Theta App is used to control the Ricoh Theta V 360 degree camera. The application allows users to wirelessly connect the their smartphone to the camera on a tripod via wifi. The application then shows a preview on the smartphone screen of the view of the camera. You can adjust positions and see on your screen the changes. The next feature of this application is the timer, which allows the user to position themself in or out of the camera frame, and hit a button on their smartphone which will take a 360 degree photo on the Ricoh Theta V camera. You can instantly view the 360 degree photo taken on the application to see if more photos are needed.

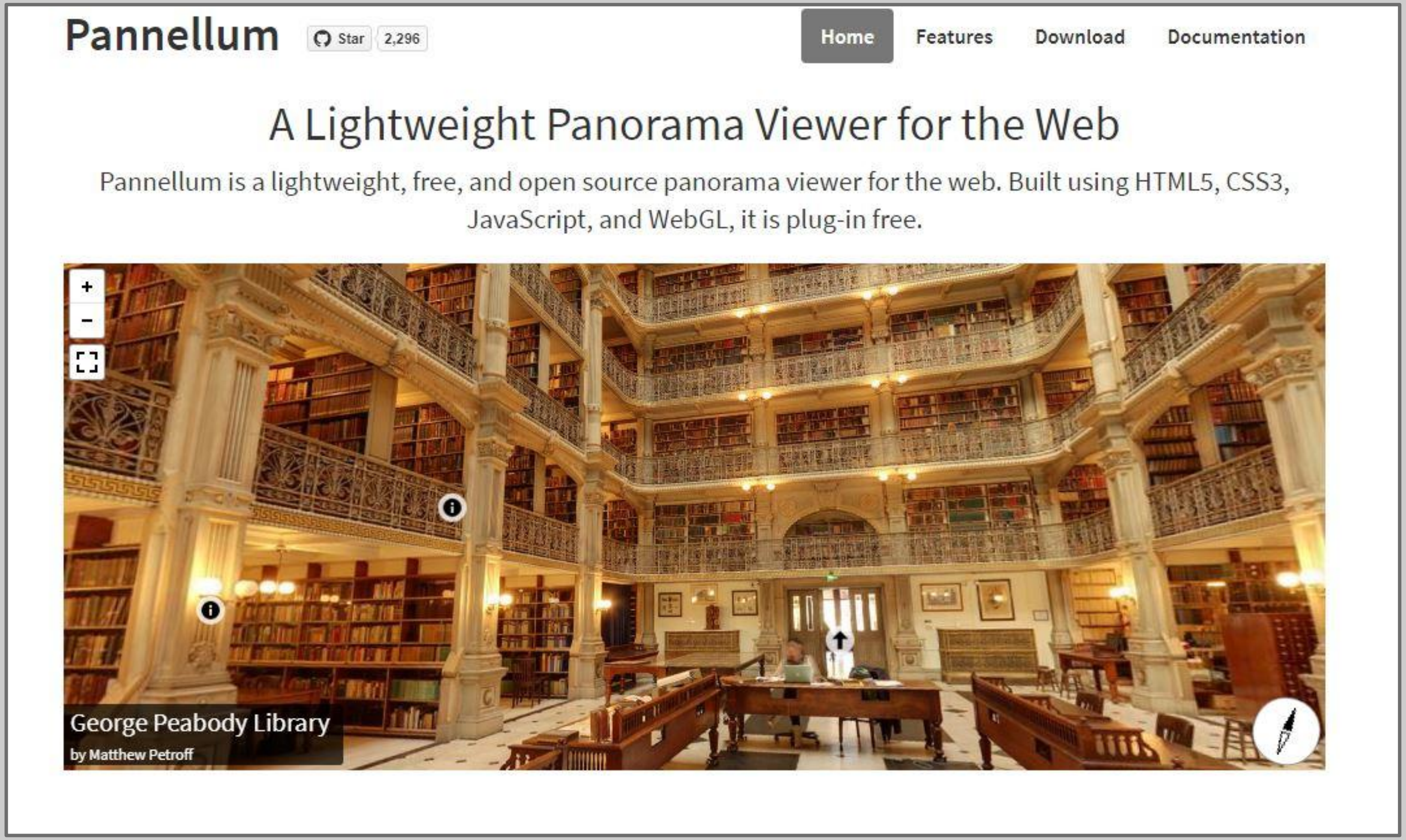
Theta App

3D Tours - Matterport

In an attempt to create engaging visualizations of bell towers, the 2016 VPC Bells team utilized software and cameras from Matterport, a company that specializes in creating virtual tours for real estate, engineering, and more. This allowed the team to create virtual "dollhouses" of each bell tower they documented. These dollhouses allowed users to view the entirety of the towers' interiors at once while also allowing them to individually enter and inspect rooms within them. Unfortunately, all tours created with this software resided on Matterport's own servers. Since there was no guarantee that these servers would remain operational, this method of visualization was eventually deemed to be unsustainable.

matterport®

3D Tours - Pannellum



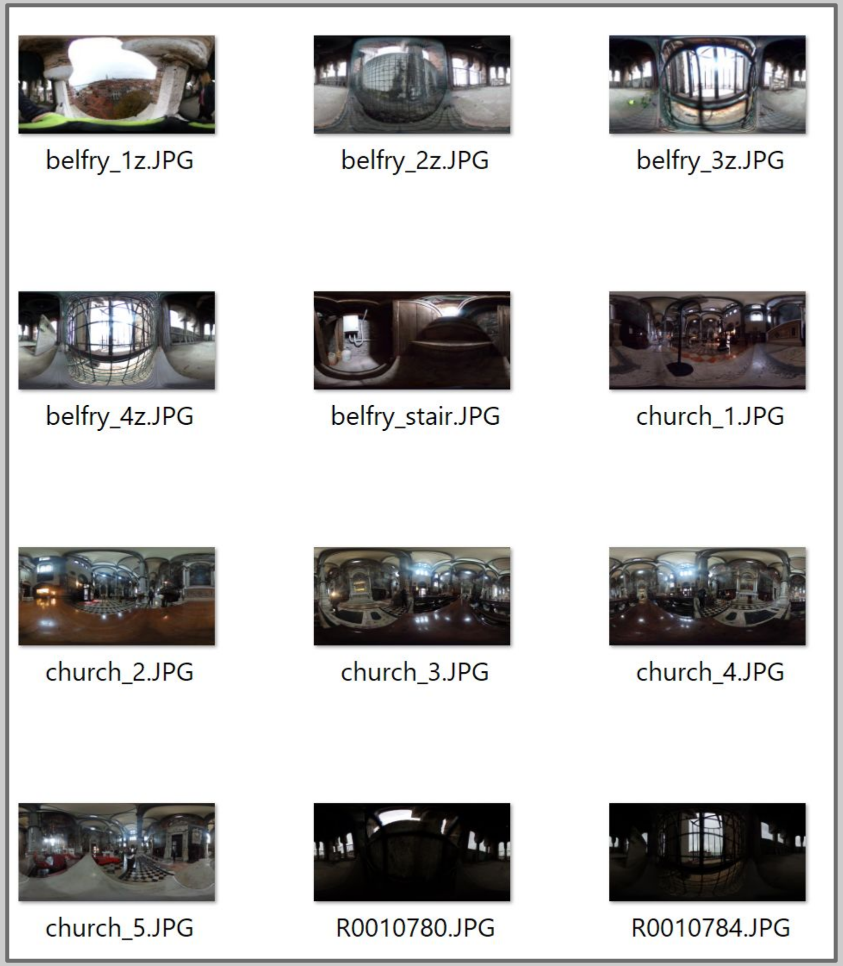
In order to create engaging tours of the bell towers that were documented, Matterport was discarded in favor of another program, Pannellum. Pannellum is an open source online panorama viewer that allows users to create their own virtual tours. Unlike the tours that were previously created using Matterport, these tours could be stored on an individuals computer, meaning a copy of the tour could safely be maintained by the Venice Project Center. Using this program virtual tours were created from 360 degree photos of the bell towers captured with a Ricoh Theta V 360 camera. Each photo was turned into a room or section of a room that users could explore, with the individual images linked together through on-screen icons. This allowed viewers to traverse the towers and their adjacent churches.

3D Tours - Pannellum: Select Images

The creation of a tour is a simple process with 3 steps.

The first step to creating a tour is selecting what images to use. A typical tour needs to have images for the base of the belfry, every landing in the shaft, the stairs to the belfry, the belfry center, and all windows in the belfry.

Each of these images needs to be named properly to be identified by the pannellum program. Adding these images to the pannellum tour is easy, just pass the image location, and give the image a unique scene_id.



3D Tours - Pannellum: Defining Hotspots

The second step to creating a tour is connecting each of the images using hot spots. The hot spots are defined in each image using pitch and yaw which are spherical coordinates. The pitch is how high the hotspot appears in the image, and yaw is the orientation horizontally in degrees.

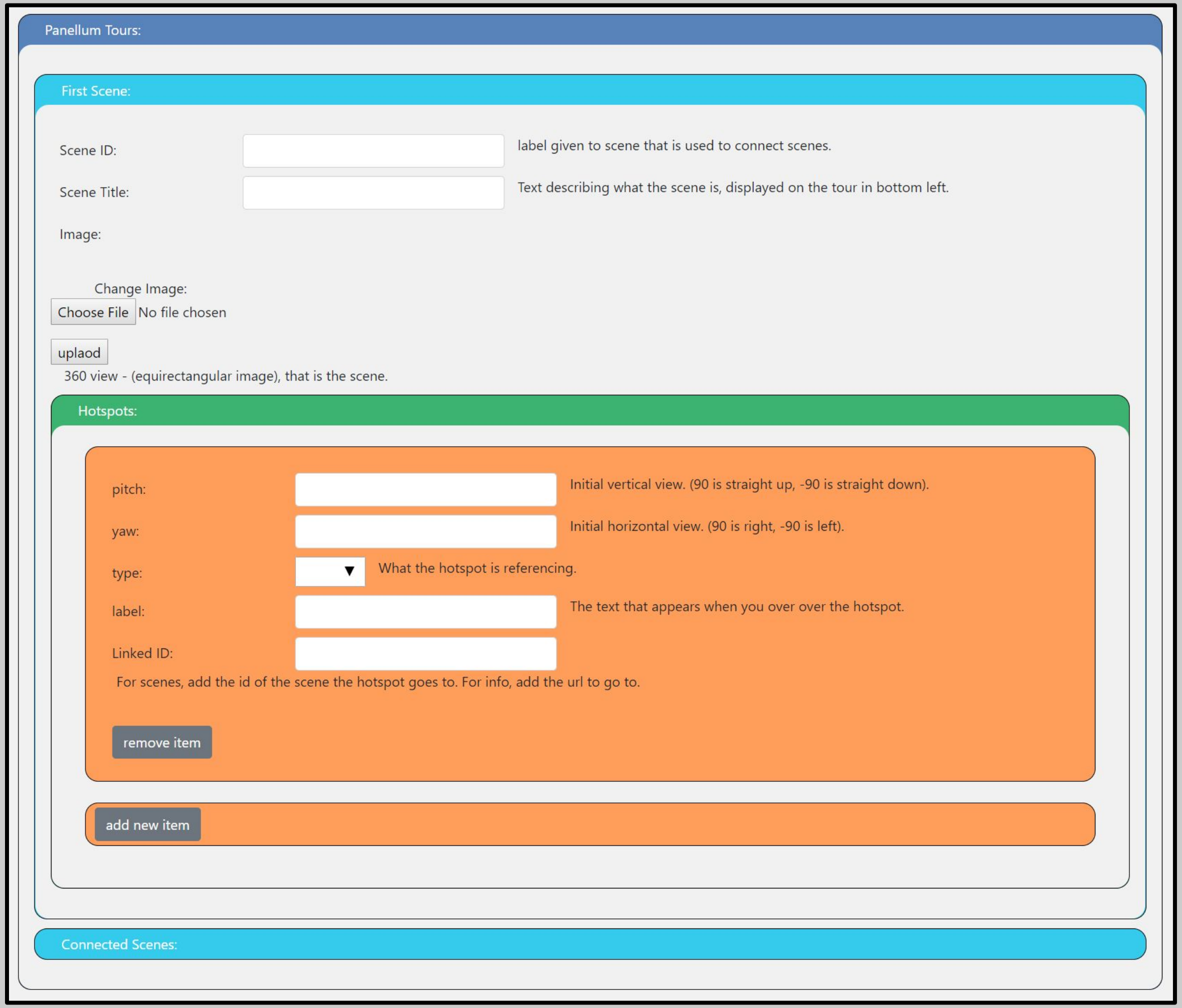
Each hotspot must be added manually and the location of the hotspot on the tours are typically found through trial and error.

To accomplish a trial and error approach, the designer must have the general pannellum tour accessible. The code for a pannellum tour is shown in Appendix G.

In the image to the right, two hotspots are defined, one of the floor and one on the window of the belfry.

Another component of the hotspot is what scene_id is linked to the hotspot. For example, on landing_2 in the shaft, typically there are two connected scenes via hotspots: landing_1 and landing_3.

3D Tours - Pannellum: Uploading Data



The third step to creating a tour is uploading data. The data is added via the input app. The setup for adding data is very similar to how the pannellum script is setup. The input app for a pannellum tour is shown on the left. A user first defines the first scene by adding a scene_id, a scene title and an image. Then the user adds hotspots with a pitch, yaw, and label. All connected scenes are added in this way. After all the data is uploaded and saved to the database, the tour appears on the bells application in the “Virtual Tour” tab.

Why Make a Tour?

Making a tour as a visualization technique allows for users to have a more complete understanding of what it is like to be inside a tower, what it is like to stand on one of the landings and look down to the bottom, and see the view from the top. It also allows for a viewer to comprehend the layout of the tower more than a walkthrough or a collection of pictures can.

It is important to allow anyone to experience the inside of a tower, and the view from the top of the belfry because what the bells team gets to do inside these towers is an immense privilege that is shared by very few people. Creating these tours allows anyone to see what it is like inside any tower where a tour has been completed.

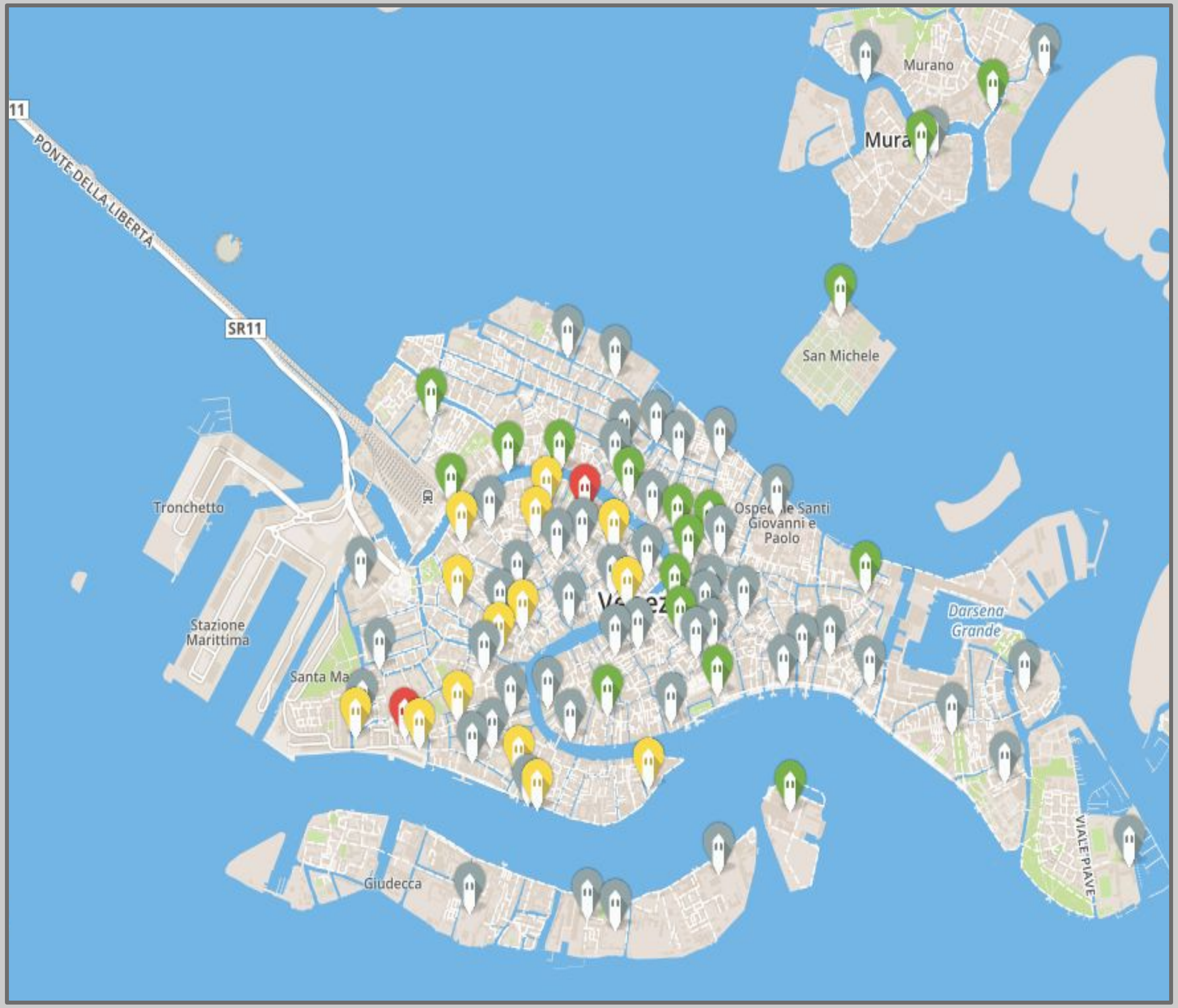
Publishing Data

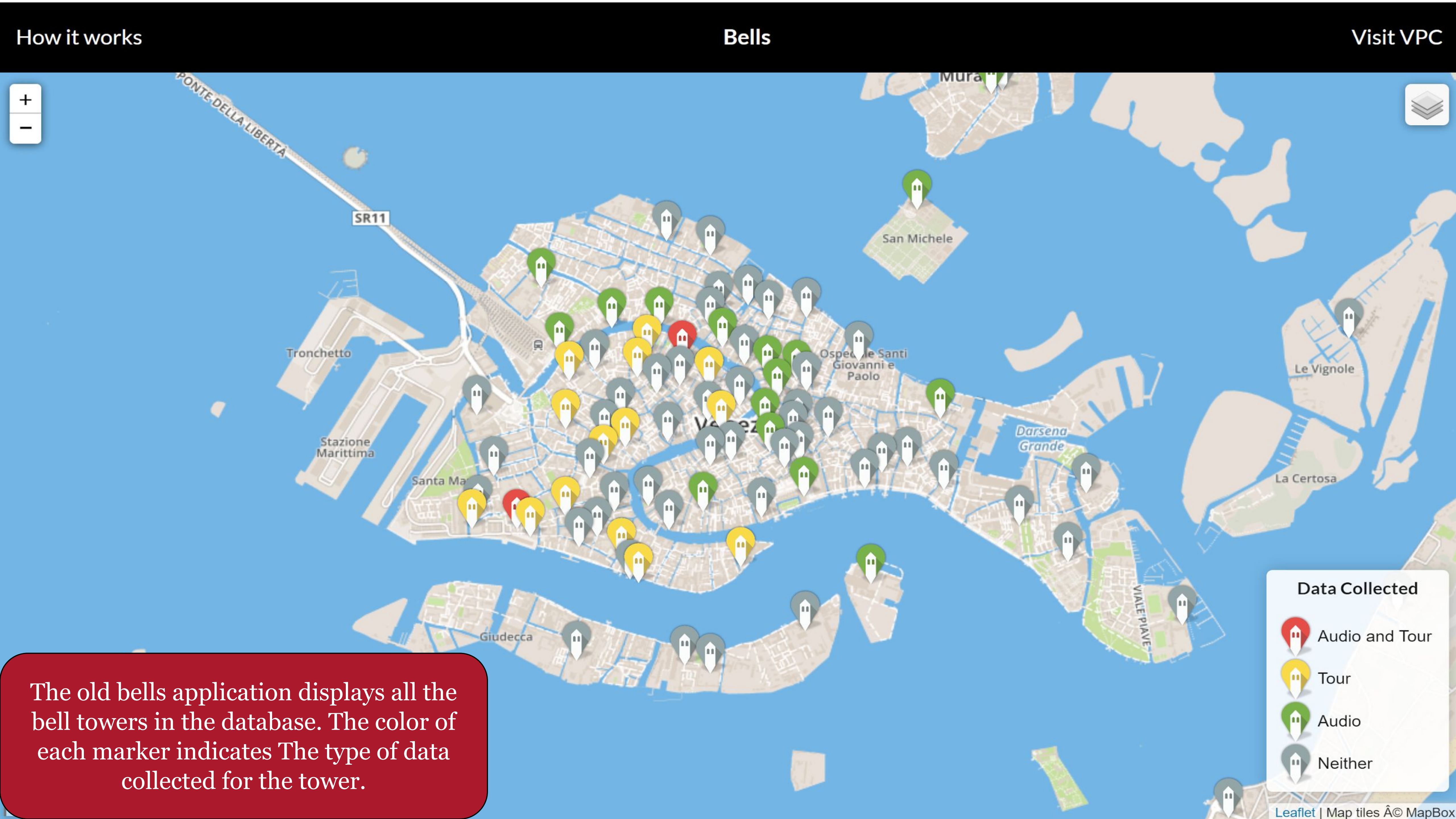
Publishing Data

After collecting data from the many bell towers across Venice and creating engaging visualizations of them, the next step of the project was developing a way to make that information readily accessible to those who sought it. While the VPC keeps comprehensive records and recordings of the towers visited in the project's early years, as well as the data collected for them, this information is not easily accessible to those outside of WPI or the VPC itself. Years ago, if someone was interested in bell tower findings, they would have to make a request with Fabio to see the corresponding files, an arduous and ultimately needless process. Thus, an online web application was established to allow users to search and locate data on all of the towers that have been documented by WPI students.

Publishing Data - The VPC Database

The online bells application was developed by the VPC to allow users to view all of the bell towers in Venice from a map of the city. The towers can be color coded by several different criteria, such as sestiere, data collected, and safety rating. Each of these towers is represented by a single icon that is linked to that bell towers information page. From here users can view all of the data that has been collected for that tower, along with images, videos, virtual tours, and recordings of the bells ringing both together and individually. Currently 67 of the 136 bells towers have been visited and documented on the application. A link to the 2018 version of the web application can be found in Appendix C.





The old bells application displays all the bell towers in the database. The color of each marker indicates The type of data collected for the tower.

Map

Bell Tower of Sant'Elena

The main page for the old bell tower! It has only one tab that displays very little valuable information.

Basic Information

Common name	Bell Tower of Sant'Elena
Church name	[[Church of Sant'Elena]]
Sestiere	Castello
Proprietor	City

Tower

Field	Data
Attic	Yes
Bell tower part	Belfry
Bell tower parts	Roof
Clock	No
Clock side	N/A
Clock working	N/A
Common name	Bell Tower of Sant'Elena
Frame material	Metal
Frame type	A
Internal wall material	Concrete

Publishing Data - Previous Database

In the early years of the VPC, data collected was not published to a website but rather stored in file cabinets. Many people outside the VPC contributed to the collection of bell tower data. Some information collected includes data on the bell tower dimensions and polaroid images of the exterior and interior. All of this is stored in filing cabinets at the VPC.

In 2012 the bells application was introduced. This application was rudimentary in that it allowed a user to display only a few data fields with hard coded images and audio files. After collecting data on a bell tower, a user would upload the information to an online database created and maintained by the VPC. The database utilized was Firebase, a Google hosted web service. The frontend application allowed new bell towers to be added to the map on the bells application, while existing towers could be edited to include more data or media files.

There were a few major limitations to this application. The most major limitation was that not all the data was uploaded to the database, therefore, it was unclear how much data on each bell tower was collected. Another major limitation was how the data was stored in the database. The database was setup using a relational database. This lead to problems because no one ever created a graphic or visual that presented this structure, so no one really understood how the database was organized. This caused problems with future years, especially with the 2016 team that tried to completely reorganize the database.

Publishing Data - Previous Database

242	Bellcode_B
243	Bellcode_B_dec
244	Bellcode_F
246	Bellcode_F_dec
252	Bellcode_floorplan
247	Bellcode_I
248	Bellcode_L
249	Bellcode_L_dec
250	Bellcode_R
251	Bellcode_R_dec
1	Bell Data
231	Bell Images

694	Bells 2019
253	Bells Audio Final
234	Bell Tower Exterior Belfry
235	Bell Tower Exterior Foundation
236	Bell Tower Exterior Roof
237	Bell Tower Exterior Shaft
238	Bell Tower Final 2014 MERGE
239	Bell Tower General
240	Bell Tower Interior
241	Bell Tower Page Final
648	belltowers MAPS 15
254	Belltowers MEDIA Nov 2014

The 2016 team realized the major drawbacks of the original bells application. The major problem they tried addressing was that much of the information inside the database was unorganized and at times incomprehensible. They decided to change the approach for how to store data in the database, so rather than being set up in a relational style database, they set up the data in a flat table style. There were four main tables they related: general, interior specifics, exterior specifics, and bells. Unfortunately, none of these tables were linked properly, and the application could only use one of the tables at a time. Furthermore, They produced these tables by "flattening" the old database. This means taking sub sections of a relational database and condensing them into a single "flat" table.

The 2016 team flattened the database incorrectly, losing much of the data in the database. The bells application remained lacking in data for the next three years.

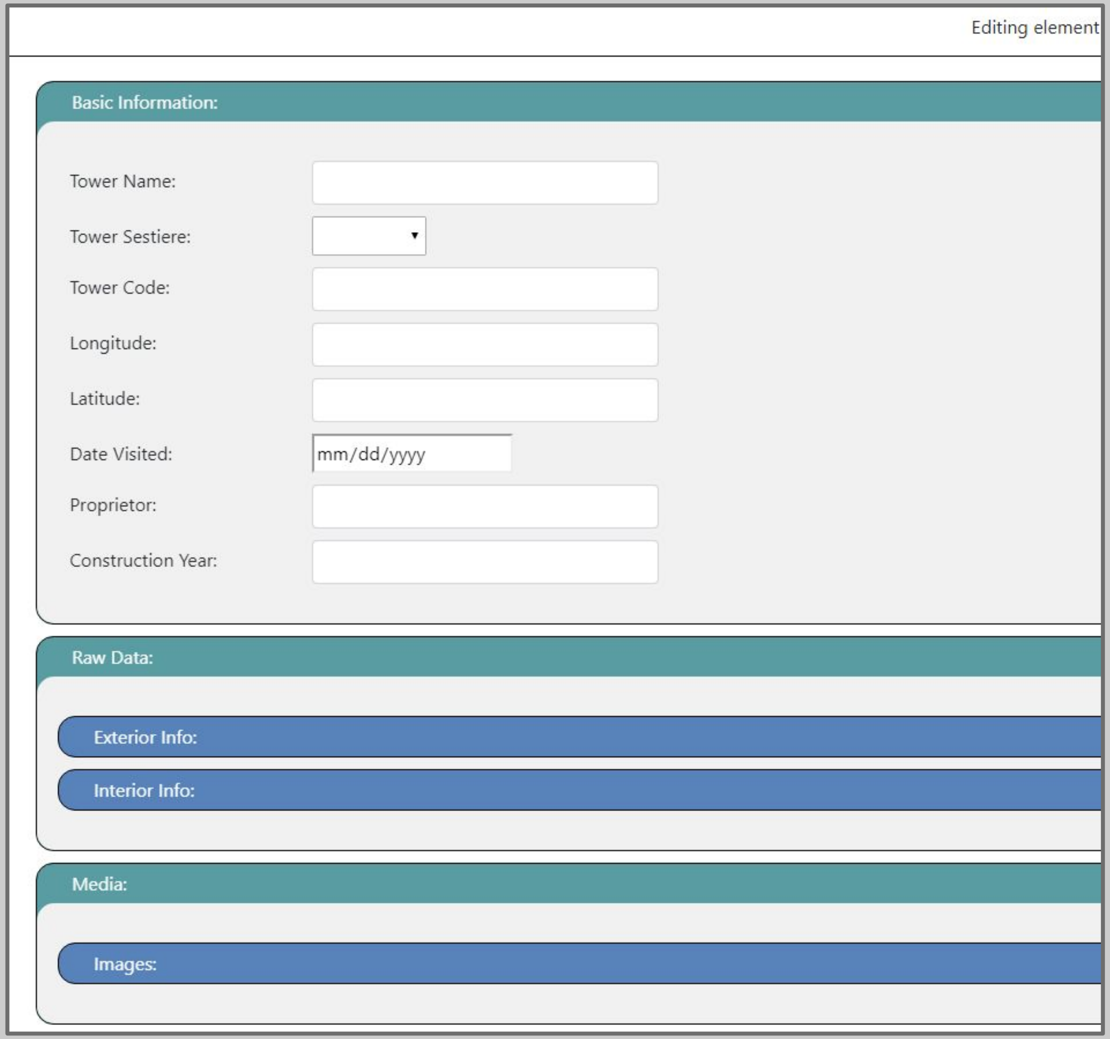
The 2018 team built on these flat tables, adding only sub sections of the total data to the database. They also migrated the database backend from firebase to a new database called City Knowledge (CK). The CK database was created by members of the VPC, using Amazon Web Services for cloud storage. The main application however, still used the Firebase.

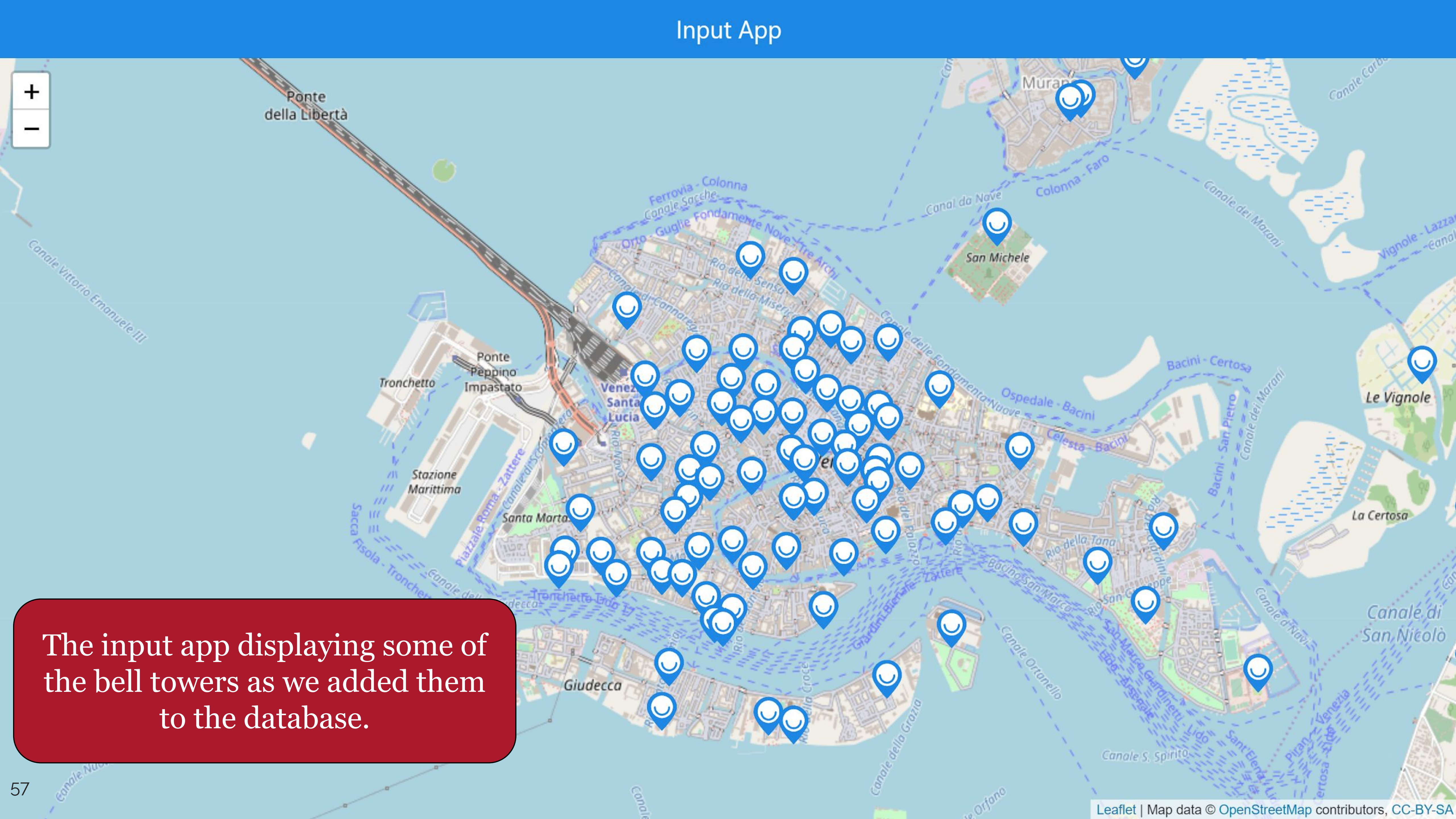
Publishing Data - New Input App

We, the 2019 team immediately identified these persistent issues with the database. The first issue ran into however was that the bells application was not set up to use data from the City Knowledge database. The first few weeks of IQP were spent reprogramming the application to use the data from the CK database, rather than the firebase. The next issue we addressed was that not all the data was stored in the database. The main issue with this was that the input app did not have an easy way to add data in a multi-tiered data structure - everything needed to be one level.

The next few weeks were spent developing the input app so that data can be added to the database in a multi-tier data structure, allowing all the data to be stored in a single table, rather than multiple tables. The new input app is configurable via a JSON config data structure, defining how the data should be organized in the database. This config file makes the new input app generalizable across all applications and backwards compatible for all CK databases.

With the new input app supporting a multi tier data structure, we began coding a new frontend to support the data structure. Starting from scratch, we rebuilt the map so that displaying various overlay's was simplified. Then we rebuilt the page that displays bell tower application, allowing for more tabs, more data, images, and audio. The last few weeks of the term were spent propagating this database with all the data from previous years. The new bell tower application keeps all the old information from the previous database, but also has much more media to display. The full methodology for uploading and editing data can be found in Appendix E.



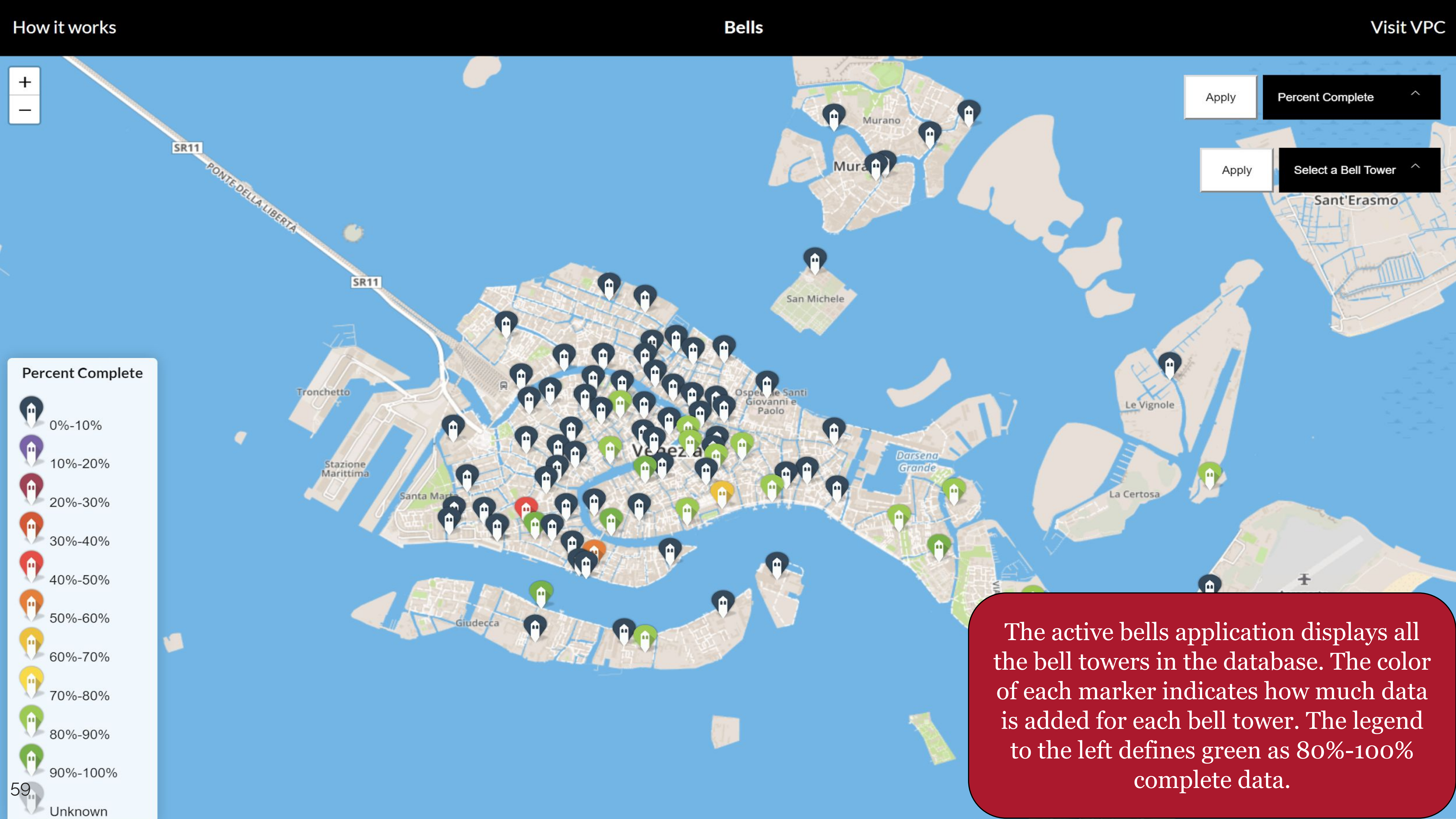


The input app displaying some of the bell towers as we added them to the database.

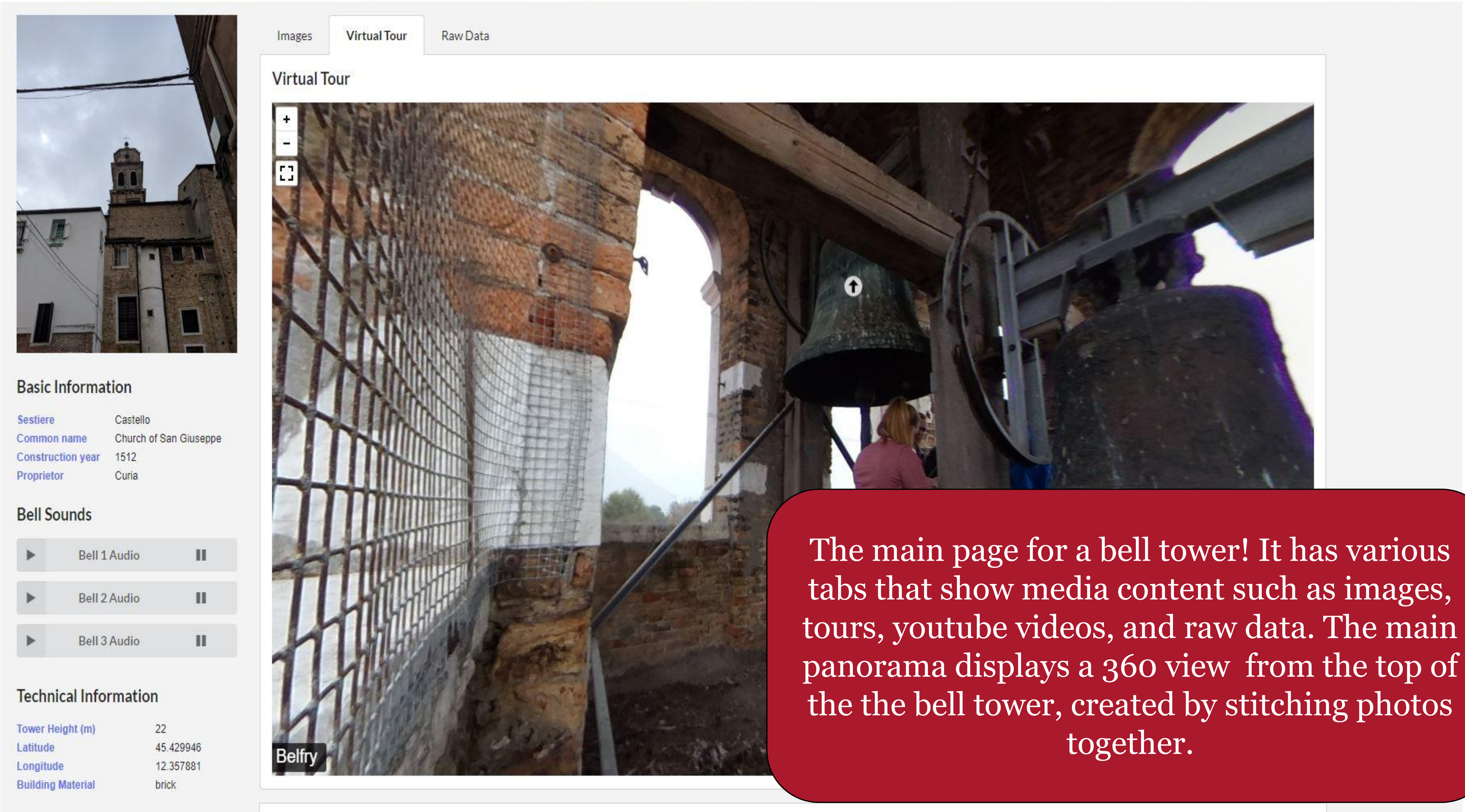
Publishing Data - Updated Site

Along with the updates to the database, the layout of the bells application was changed as well. Now not only could towers be sorted by fields such as frame types and sestiere, but also the percentage of overall data collected for that tower.

The individual page structure for each tower was modified as well, with seperate tabs for raw data, virtual tours, and image files. This new layout not only provides a more comprehensive set of readily available data for each tower, but also an efficient way to track what towers currently lack data and thereby need to be further researched or visited. A link to the new web application can be found in Appendix D.



The active bells application displays all the bell towers in the database. The color of each marker indicates how much data is added for each bell tower. The legend to the left defines green as 80%-100% complete data.



The main page for a bell tower! It has various tabs that show media content such as images, tours, youtube videos, and raw data. The main panorama displays a 360 view from the top of the the bell tower, created by stitching photos together.

Basic Information

Sestiere	San Marco
Common name	Church of San Moisè
Proprietor	Curia

Technical Information

Tower Height (m)	32.65
Latitude	45.432295
Longitude	12.336308
Building Material	stone and brick

Images | Virtual Tour | Panoramas | Raw Data

Exterior Info:

General:

Tower Height:	32.65
Material:	stone and brick
Block Height (cm):	4.5
Block Width (cm):	10.15
Block Depth (cm):	3.5

Orientation and Inclination of Tower:

Front Orientation (Degrees):	70
Right Orientation (Degrees):	340
Back Orientation (Degrees):	250
Left Orientation (Degrees):	160
Inclination Rating:	0 (none)
Inclination Front Back (Calculated):	0.1
Inclination Left Right(Calculated):	0

Public Access:

Accessible to Public:	No
Accessible from Front:	Yes
Accessible from Right:	No
Accessible form Left:	No
Accessible form Back:	Yes
Exterior Door Front:	No

The raw data tab of the bell tower application displays all the data stored on the bell tower. It is displayed in a structure formatted in the way that the data is collected. For example, this image displays the exterior information, with general info, orientation and inclination, and public access.

Results & Moving Forward

Towers Visited in 2019

San Giuseppe

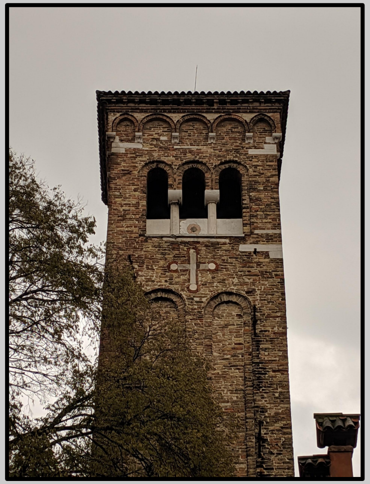
San Francesco di Paula

San Pietro

Sant'Elena

San Moise

San Zaccaria



Santa Maria Formosa

San Vidal

San Zulian

2019 Findings - Problems Encountered

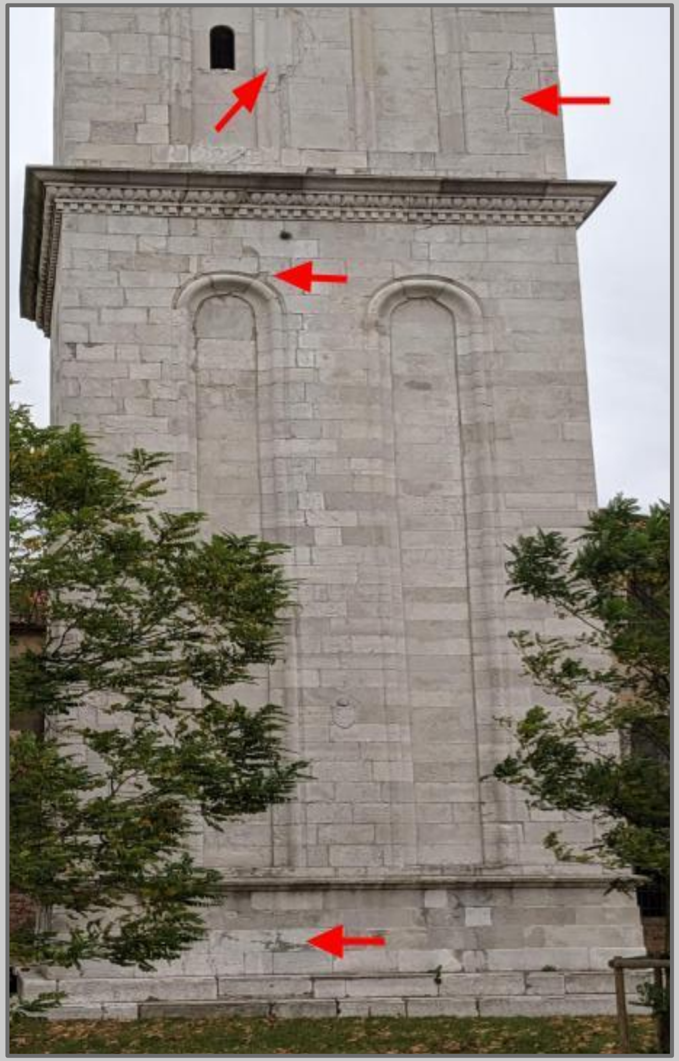
After visiting these towers, there were a few problems we observed that should be monitored and fixed if possible. A common issue we saw was dirtiness, there was often dust, dirt, and random debris build up throughout every tower. The most significant was San Giuseppe, with several inches of dirt buildup throughout the shaft and in the belfry, as well as two bird carcasses, one in the belfry, and one at the bottom of the shaft.

Also at San Giuseppe, one of the bells was incorrectly repaired. Several thick metal blocks were attached to the bottom of a damaged clapper. This caused significant damage to the bell every time it was rung, and needs be repair, or the bell should not be rung.

2019 Findings - Problems Encountered

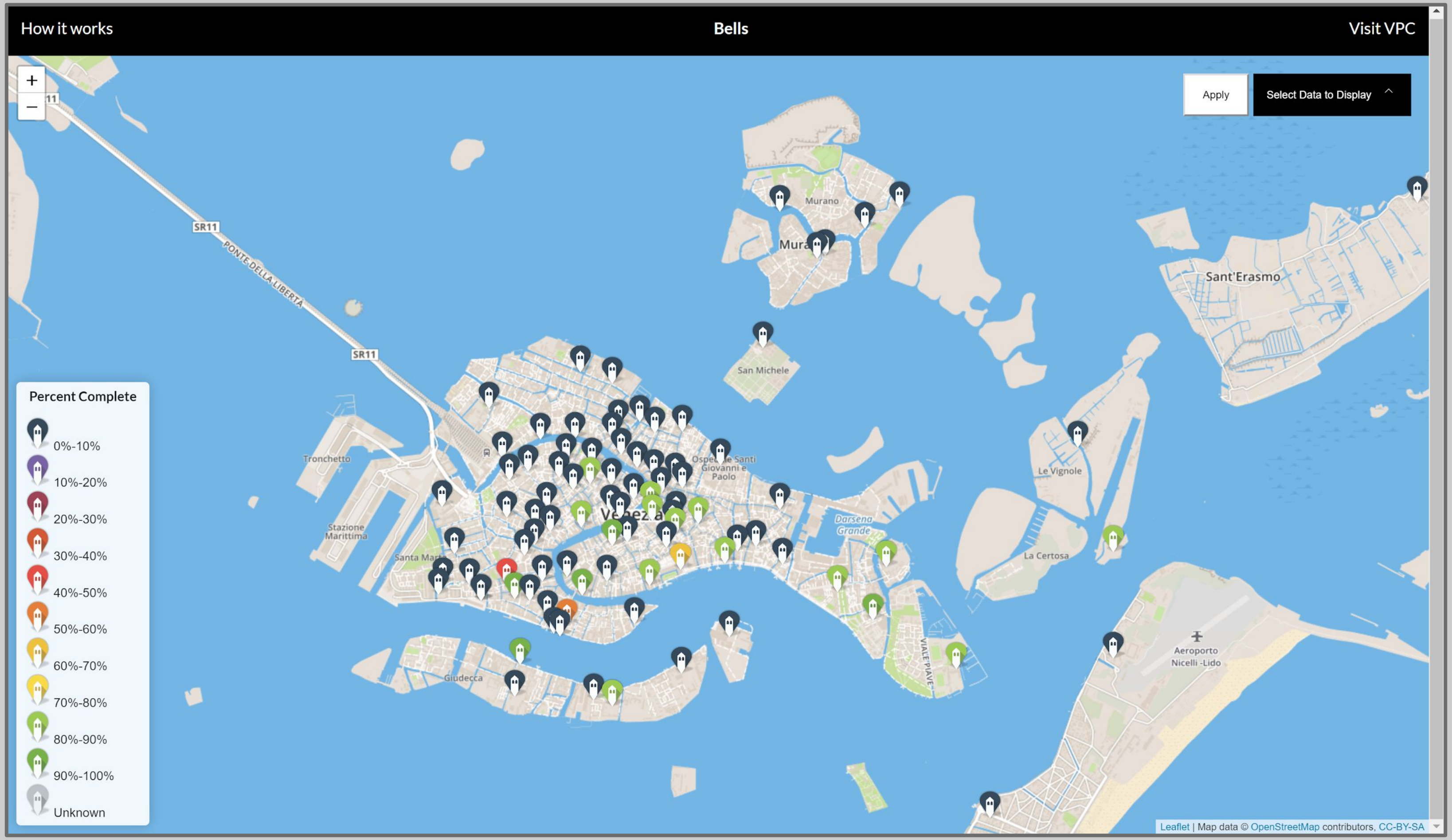
The biggest issue we encountered was the significant tilt observable in the tower of San Pietro. There was a 3 degree tilt towards the right and the back, a significant amount for a 40 meter tall tower. Around this tower is the church, a residential building, and a middle school, that are all within a possible danger zone if the tower were to collapse.

The tower also had a large number of long cracks on the foundation and the shaft of the tower. These can be addressed in the short term via the use of tie bands, but none were present at the time of recording this data.



Repopulated Database

The new database created has also been repopulated with data from every bell tower the 2019 team visited, as well as most of the towers from the last three years' team. Future teams will be able to use the input app to upload data that the 2019 team was not able to complete, especially data stored on the paper forms.



An Ongoing Project

Currently, 67 of the 136 bell towers in Venice have been documented through this project, with many now viewable in the online bells application. Additionally, the recently updated database and input application have created a sustainable and efficient framework for future teams to continue visiting and documenting the remaining towers throughout the city. Additionally, reliable software for creating more 3d virtual tours was located and can be utilized by future teams. With all of the improvements made to the methodology of recording and storing data, this project can now be completed in a quick and precise manner.

Appendices

Appendix A: Tower Data Collection Form

Appendix B: Tower Data Collection Results

Appendix C: 2018 Bells Application

Appendix D: 2019 Bells Application

Appendix E: 2019 Input App

Appendix F: Future Team Instructions

Appendix G: Pannellum Tour Code

Appendix H: 2019 IQP Folder

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Image Citations

https://www.myveniceapartment.com/wp-content/uploads/2015/12/Chiostro-Madonna-dellOrto-5.jpg

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