FAST & CHEAP, STABLE & REUSABLE

Reimagining Touch-based Interactive Installations at SFO Museum during the COVID-19 Pandemic

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The SkyTerrace at San Francisco International Airport (SFO), showing SFO Museum's hands-free interactive map installation and other displays in 2021.

PHOTOS BY AUTHOR AND SFO MUSEUM

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Fig. 1. The Mills Field website allows viewers to see how the airport has transformed over time.

Opened in the fall of 2021, *Mills Field and the San Francisco Airport* traces the evolution of San Francisco International Airport (SFO) from a temporary airfield opened in the mid-1920s to an international airport that serviced 58 million passengers in 2019.[1] The exhibition is located in the airport's SkyTerrace, a publicly accessible observation deck located in the Terminal 2 facility with an outdoor viewing platform and indoor seating area with galleries and programming provided by SFO Museum. *Mills Field and the San Francisco Airport* includes an interactive map installation that allows visitors to view the transformation of SFO as it is captured in over three dozen aerial maps created between 1930 and 2022 (intro image).

Originally designed as a touch-based application meant to work entirely offline, the map interactive was updated in 2021 due to health and safety concerns raised by the COVID-19 pandemic to allow visitors to control the maps "touch free" using their personal mobile devices. These changes resulted in a final application at launch that was considerably more complex than originally designed. In-house staff at SFO Museum developed, iterated, and maintain the application – were this not the case, it is unlikely that the museum would have had the resources necessary to transition the application from a touch-based to a hands-free interaction model, especially given the project's timeline. Indeed, it is unlikely the application would have been developed at all given the cost of outsourcing this kind of application development.

In addition to being produced in-house, the application uses consumer-grade hardware and web-based technologies. Our team's goal was to develop a fast, cheap, and reusable template for building interactive installations in order to create a system for building future displays with minimal hardware requirements and stable costs that can function both online and off in any four-by-four-foot area at the airport. The aim is to allow the museum to produce, install, and test interactive applications at a fraction of the time and cost of past efforts and to help foster a culture of experimentation where "failure" isn't understood as catastrophic. Ideally, the museum can reach a point where the scaffolding and infrastructure necessary to build and install interactive applications is inexpensive enough that it becomes cost-effective to deploy experimental work – if only to learn what does and doesn't work. In that vein, this paper aims to demonstrate what a dedicated and knowledgeable staff makes possible and to argue that in-house technical staff are not a "nice-to-have" luxury but a necessity if museums and institutions hope to meet the public's expectations around digital technologies.

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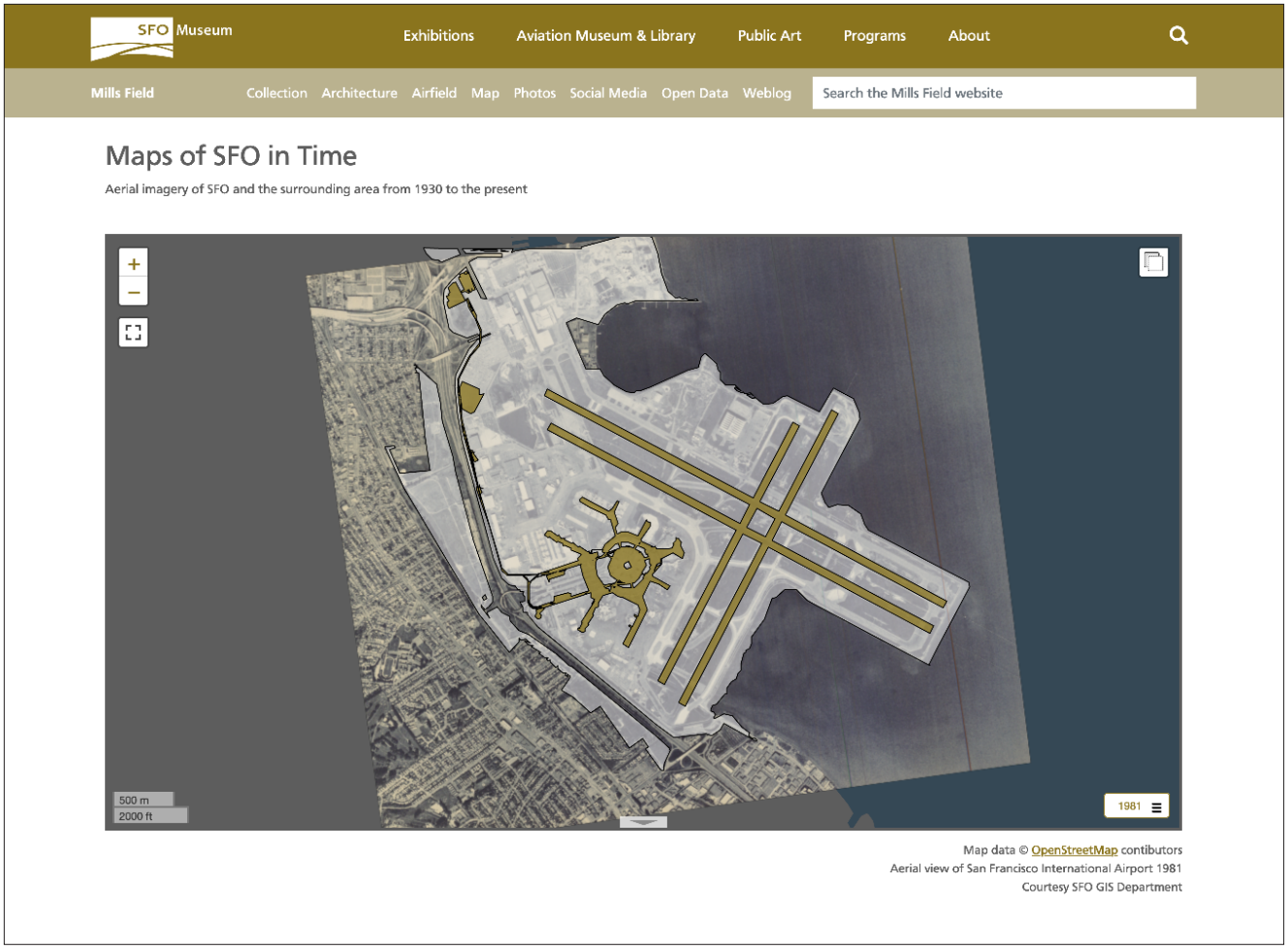


BUILDING THE INTERACTIVE

Origins

In 2018, SFO Museum began to focus its attention on contemporary and historical maps as one way to tell the story of the airport and of the museum's aviation collection, writing:

> Location and place, as you might imagine, are core to an airport. [...] We need and want maps to contextualize our collection whether it's where an object was created, where the institution that lent us an object is located, where in the airport that object is on display or where on the larger campus a photo from the archive depicts. [...] We also want a variety of different maps. We want maps for way finding but, equally, we want stylized maps whose function is to be the soundtrack to a larger story. We want historic maps to help people understand the evolution of the airport and the museum itself. [2]

These ideas took the form of an interactive map on the museum's Mills Field website, built using web technologies and consisting of a contemporary base map overlayed with historical aerial imagery of the airport (fig. 1).[3] The images are sourced from the

museum's own collection, the airport's Geographic Information Systems (GIS) department, and the Aerial Photography Collection at the UC Santa Barbara Library. Our goal continues to be to collect aerial imagery for every year of the airport's existence. Eventually, we hope to be able to use the tools and infrastructure we've built for SFO to visualize the history of other airports that relate to the museum's collection.

Early Plans

When SFO Museum became responsible for programming the still-under-construction SkyTerrace space,[4] staff proposed creating an interactive installation derived from the historical maps application first developed for the Mills Field website.

We decided early on that the interactive needed to run offline. An offline application would remove some of the unique security challenges around network-enabled applications running in an airport environment and not require additional time and resources from the airport's IT and security staff, who were already busy running an airport.

We designed the installation to consist of a single-person touch-screen device mounted inside a label rail at or near waist level and mirrored to a large external display mounted to the wall (fig. 2). These two hardware devices – a touchscreen and an external display – are referred to as the "controller" and "receiver," respectively. Additionally, the controller needed to display a QR code, updated as the map

Fig. 2.

An early prototype of the SkyTerrace interactive map installation.

Fig. 3.

In the touch-based version of the interactive, the controller was embedded in a label rail.

changed, that would allow visitors to save and share a view of the airport at a particular time and place.

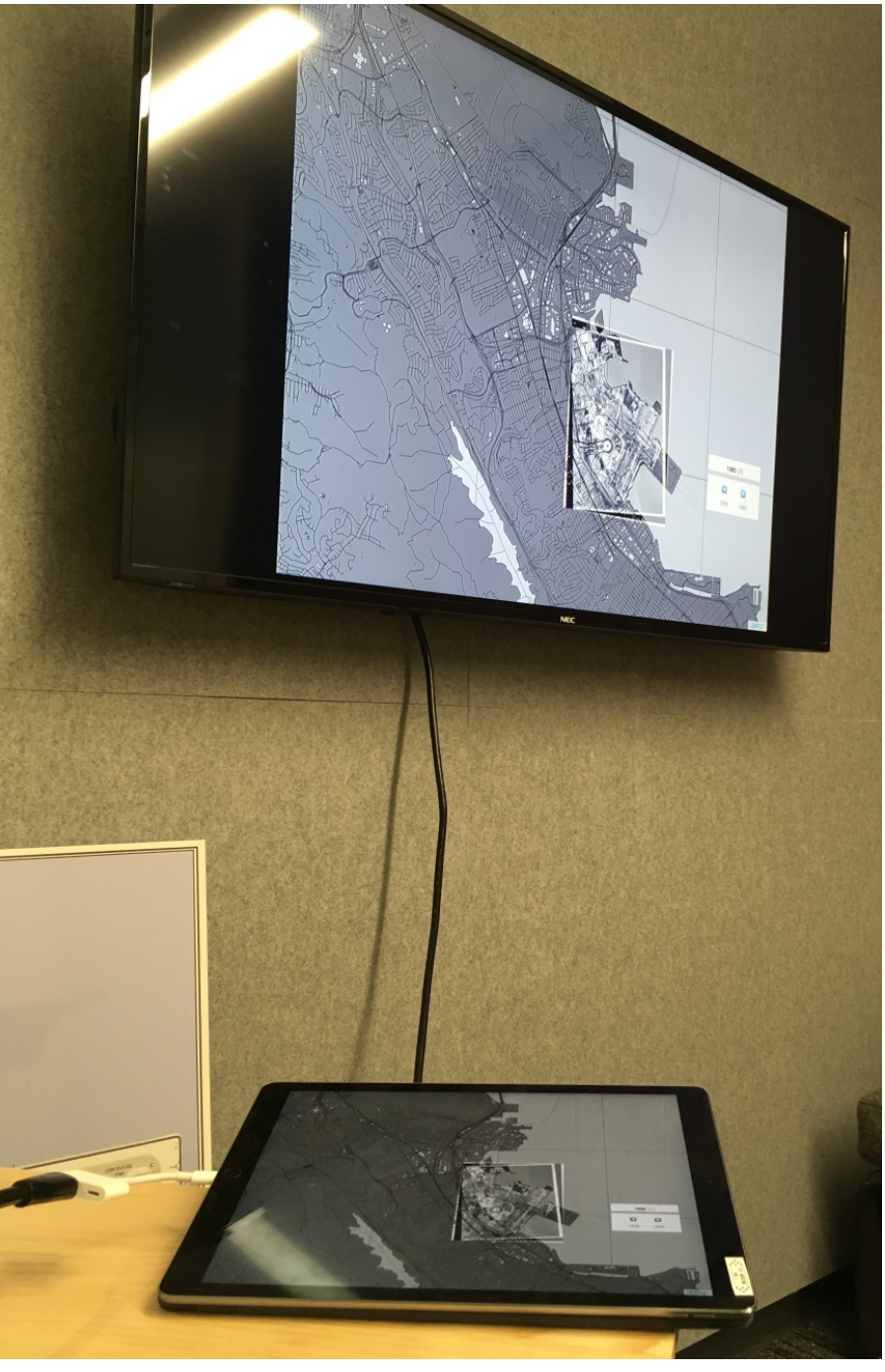
While the controller would only be visible to the person using it, we wanted the receiver to be visible to anyone in the SkyTerrace's indoor space. In this way, other passengers could familiarize themselves with the application and "learn by watching" as others explored the maps. The person using the interactive would, in effect, become the "call to action" inviting other passengers to participate.

Accessibility was an important consideration in the application's development. Had we opted for one touch-enabled display mounted to the wall, all passenger-facing controls and interactions would have needed to be contained in the bottom third of the screen – the top two-thirds being out of reach of children, passengers in wheelchairs, and others, which would both create a suboptimal visitor experience and violate access requirements of the Americans with Disabilities Act (ADA). A device embedded in a waist-high label rail guarantees that the interactive is accessible to passengers whether they are short or tall, standing or seated (fig. 3).

The Budget

The hardware costs for this project were less than $4,000 and included one 55-inch bezel-less display monitor (the receiver); three 12.9-inch third-generation iPad Pros (the controller); and a power-ethernet-HDMI adapter.[5] The bulk of this cost was for the iPads. For development and redundancy purposes, the museum purchased three: one for production use; one for development and

Fig. 4. Prototype for the SkyTerrace interactive map showing both the controller and receiver.



debugging; and one standby unit in case the others failed. Our decision to use an iPad for the controller (fig. 4) was based on several factors that any museum undertaking a similar project will want to consider:

- *Built-in and best-of-class touch-screen support.* The responsiveness and durability of Apple's touch-screen hardware and its integration with other applications exceeds any other similar offerings.

- *Processing and storage.* The processing power of iPads has begun to exceed that of desktop and portable computers making the device an attractive platform for developing feature-rich interactive applications.

- *Single-application mode.* Apple develops and maintains tools for securing access to an iPad so it can be configured to run a single application as though it were a dedicated kiosk.

- *Ease of replacement.* The remedy to an imagined "failure scenario" was simply to drive to the nearest Apple store, purchase a new iPad, configure it, and deploy it to the floor in a matter of hours rather than the days or weeks it might take to requisition and process a change order with a vendor for different equipment.

Thus, while Apple products are typically more expensive than similar consumer products, these up-front costs are known and can be easily budgeted for. Additionally, they are often more than made up for by the units' processing ability, ease of use, and ease of replacement.

A significant factor that kept the overall budget for this project so low is the fact that SFO Museum has dedicated, in-house staff capable of assuming all work associated with the interactive display. All enclosures and fabrications related to the installation were performed by museum staff as part of their regular exhibitions-related duties, and software development was also done in house by dedicated digital staff. Not only did this save money, but it also allowed the work to unfold in a series of sprints over the course of 18 months, rather than as a single, coordinated block of work. In approximate terms, initial development took two to three months of dedicated staff time; updating the application to work hands-free required one month; and debugging and accounting for bugs introduced in iOS post launch required two to three weeks. When outsourced to external vendors, it is not uncommon for budgets for projects of similar scope and duration to exceed six figures. Knowing that more and more museumgoers expect digital experiences to be a part of their visit, institutions should consider how budgeting to hire dedicated digital experts could save money in the long term while also delivering on visitor expectations.

SOFTWARE DEVELOPMENT: TO APP OR NOT TO APP?

Initially, SFO Museum did not want to develop a native iOS application, despite settling on the iPad as a hardware platform. Instead, we hoped to reuse and adapt the web application developed for the Mills Field website to facilitate development, testing, and debugging time. This would also prevent the application from becoming overly dependent on Apple's native platform, which might risk vendor lock-in and hamper future development.

Open Source: Promise and Current Limitations

Although the SkyTerrace interactive application was only being deployed to a single hardware device, SFO Museum was keen to use its development as an opportunity to investigate how open-source development platforms Electron or Cordova might be applied to future projects.[6] Native mobile application development is a time-consuming endeavor under the best of circumstances. Given the time and budgetary constraints that the cultural heritage sector operates under, the costs of developing native applications can be so prohibitive as to seem impossible. The introduction of frameworks like Electron and Cordova suggests another avenue by which museums might be able to develop and deploy applications for mobile devices without the need for expensive third-party vendors.

Ultimately, however, we were not able to adopt either technology for the SkyTerrace interactive due to interface and interaction requirements that have yet to be addressed by existing web standards.[7] Although the controller was meant to mirror the map application to the receiver, we did not want the former's various interaction controls (e.g., controls for selecting aerial imagery by year) to appear on the latter. This necessitated a single application with two separate but synchronized "views." To achieve these results, we realized that we would, in fact, need to develop a native iOS application.

The App

Rather than developing a purely native iOS application, we opted to develop a minimal

native application that would "wrap" our existing web application. To accomplish this, we took advantage of Apple's application ecosystem, which provides an interface widget called a WebKitView[8] element that encapsulates a web-rendering engine.[9] Importantly for our purposes, WebKitView elements can communicate directly with the native applications that parent them, making it possible to relay messages between two independent WebKitView elements using the parent application as a message broker.

We were able to develop an application whose only responsibility is to manage two different WebKitView views (i.e., the controller iPad and the external receiver display) and to relay messages from the former to the latter (fig. 5). This enabled us to leverage the performance of a natively compiled iOS application, in addition to functionality not available on other platforms, while ensuring that the core application was developed using web standards, thus reducing development time and the risk of vendor lock-in.

This approach opens up the possibility of using underlying technical scaffolding to quickly and cost-effectively develop new and different interactive installations as web applications. It is an interaction model that assumes a single, active user controlling the interactive and multiple, passive viewers, which, it turns out, is a model that is well suited to a busy airport or museum.

COVID-19: THE HANDS-FREE PIVOT

On March 16, 2020, the beginning of the COVID-19 pandemic in the United States called into question the cultural heritage sector's long bet on touch-based interactives: concerns around contracting COVID-19

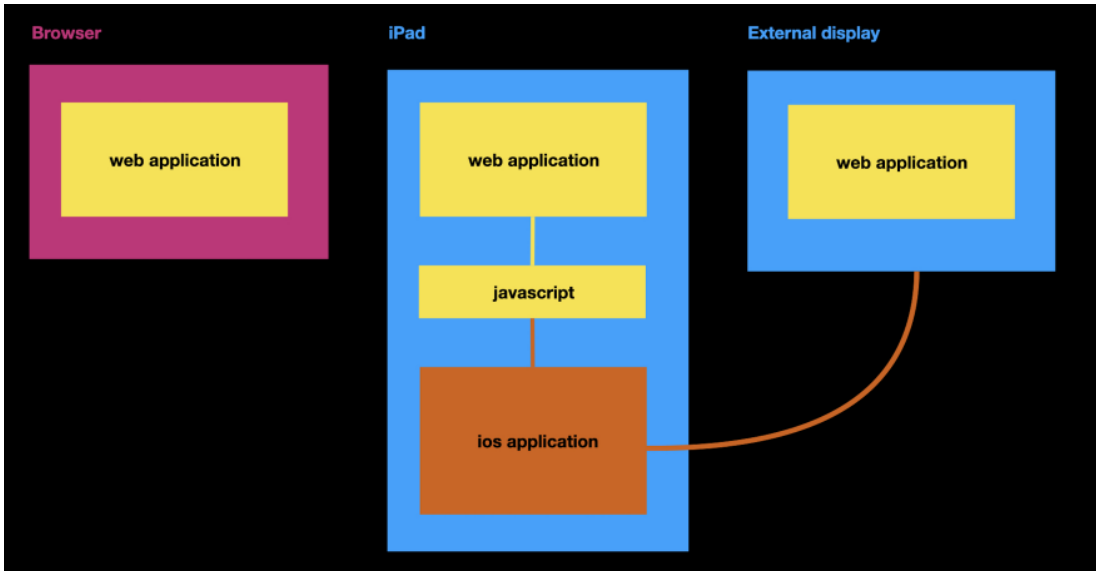


Fig. 5.
Architecture diagram for the application.

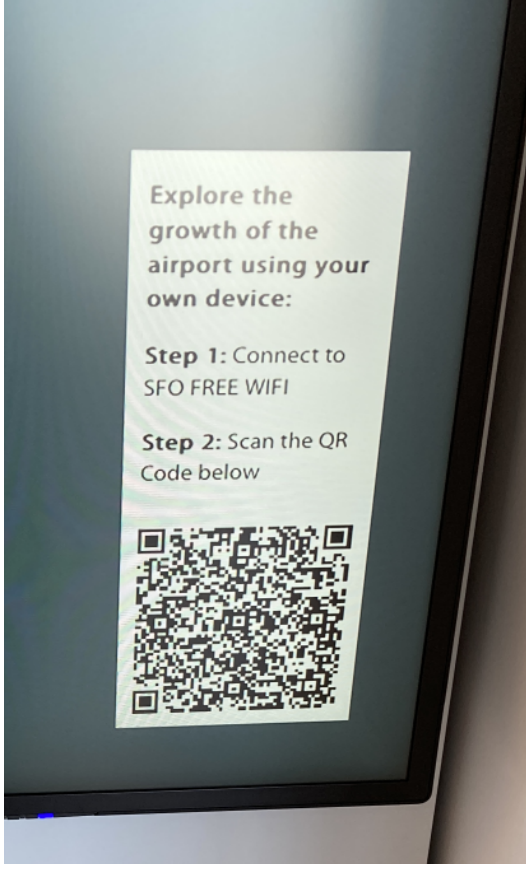


Fig. 6. A QR code invites visitors to explore the interactive using their own personal mobile devices.

made most people afraid to touch many, if not all, public surfaces. These concerns, which will long outlive COVID-19 specifically, have forced a reconsideration of touch-based interactive models everywhere.

As passengers began to return and traffic increased throughout 2021, the airport renewed its plans to open the SkyTerrace. As part of those efforts, the museum was asked whether the map installation could be made to work hands free.

To adopt a hands-free approach, we needed to create a new hosted service that would broker and relay messages from a passenger's personal device to the controller iPad application, which, in turn, would relay those instructions to the receiver display. This new service, eventually dubbed the "relay server," was developed as a web application with the following responsibilities:

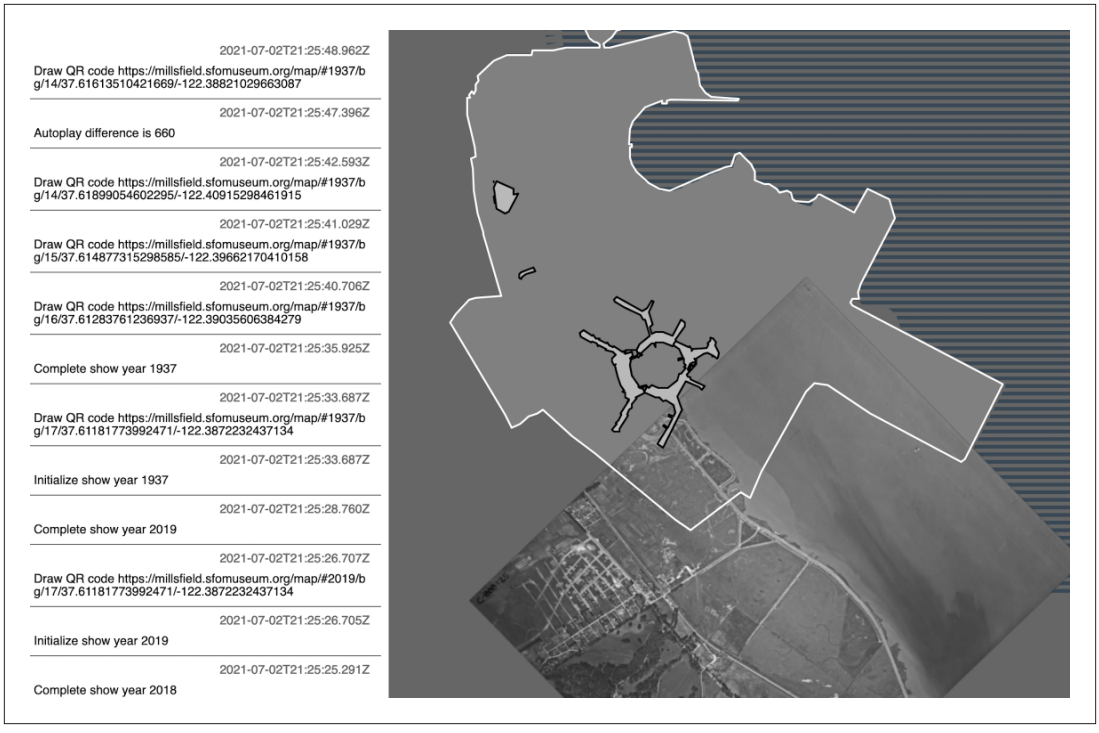
- Display the same web-based application originally displayed on the controller on a passenger's device.
- Create a bidirectional channel between the map application running on a passenger's device and the relay server, allowing the former to send events to the latter.[10]
- Create a unidirectional channel between the relay server and the controller, allowing the former to send events to the latter.[11]
- Maintain a database of time-sensitive access codes and relay them to the controller application via the unidirectional channel described above. These codes would then be displayed on the interactive's receiver, where they could be scanned by passengers to access the interactive on their personal devices.

When the controller receives a new access code from the relay server, it is encoded and displayed as a QR code on the receiver (fig. 6). Once that QR code has been scanned by a visitor and used to load the web-based controller application on their mobile device, the relay server sends a command telling the iPad application to hide the QR code. This allows a single user to control the map for a fixed amount of time before a new QR code grants control to a different individual. Access codes which have expired will continue to work until a newer code is redeemed, so, if no one else requests access, an existing session will continue for as long as the user desires.

In addition to designing, developing, and debugging the relay server, museum staff had to update the iPad application to account for these changes. First, we removed the iPad from the label rail and hid it from view. Second, we updated

Fig. 7.

A debugging session to work through issues introduced by an iOS upgrade.



the native iPad application to establish a communication channel with the relay server and to dispatch messages received to the controller view. Finally, we had to update the controller view to listen for those messages and use them to update the map.

Importantly, no changes were necessary to the WebKitView on the receiver since it was already configured to receive events from the controller. All that changed was the mechanism by which those updates were triggered. Previously the map on the controller was manipulated by a passenger's finger touching the screen of the iPad. Now the map would be moved by instructions relayed from a mirror application on a passenger's device to the relay server which would transit those instructions to the WebKitView on the controller. But for visitors watching what was happening on the large SkyTerrace display, it was as though nothing had changed.

LAUNCH

The SkyTerrace opened to the public in September 2021. The hands-free interactive map installation has been running without interruption ever since.[12] The application itself has not required any significant software updates or bug fixes.[13] Despite the complexity of the architecture required to support a hands-free application, it has proven itself robust and continues to operate as designed with little to no intervention.

Because we developed the software using the existing Mills Field website map application, most of our initial development time was spent picking a platform (iOS versus Cordova or Electron), determining strategies and tools for storing and rendering the large volume of map tiles required by the application, and optimizing those solutions to ensure the application remained performant. Transitioning the application to

support touch-less interactions was faster than expected due to the maturity and broad support for technologies like WebSockets and Server-Sent Events in both iOS and server environments (fig. 7). Because of the way we had designed the application there was only a small code surface that needed to be modified. We spent an equal or greater amount of time configuring network resources to limit the lag between when a person moves the map on their device and when those changes are reflected on the receiver.

So far usage and uptake of the interactive have been slow due to several factors:

- The volume of passenger traffic through SFO has not yet returned to pre-pandemic levels.
- The SkyTerrace has limited operating hours and is located pre-security, which means its audience is limited to passengers with enough time to visit before going to their gate, passengers visiting after a flight, or people waiting to meet arriving passengers.
- Active promotion of the SkyTerrace has been limited, so public awareness remains low.
- Finally, despite the rapid proliferation of QR codes during the pandemic, it is not clear whether they help or hinder use.

At this point, it is not clear whether a hand-free interaction model is better – or at least better suited to the SkyTerrace interactive map installation – than a touch-based approach. Though this author thinks not, that opinion is moot given the contemporary environment of concerns. Importantly, the switch to hands free did not mean we removed the touch-based interaction model. Rather, the application has a toggle that will allow the museum to switch between the two if and when the public mood toward communal touchable surfaces changes.

CONCLUSION

The primary goal of the interactive was to develop an engaging application for passengers that revealed the airport's transformation over time. Questions remain as to whether this has been accomplished for the reasons described above. If, however, a larger goal has also been "to create a system for building interactive displays with minimal hardware requirements and stable costs that can function both online and off in any four-by-four-foot area at the airport," then we have at least accomplished this much and can now do these things using more interaction models than when we began.

The museum has demonstrated, both to itself and to the rest of the airport, that it is possible to develop robust, long-running, and sophisticated applications and to do so within operational and budgetary boundaries. This was only possible because the museum has invested in dedicated technical staff. Sadly, this kind of staffing commitment remains the exception in many cultural heritage institutions.

SFO Museum is committed to being as generous with its efforts as time and circumstances permit. We try to do this by sharing our experiences and as much open-source software as possible.[14] But we also know that these software releases will not make up for the deficit of technical staff in museums, libraries, and galleries; in fact,

much of the software that SFO Museum publishes requires technical staff to be able to adopt.[15] These releases are predicated, as stated earlier, on our belief that in-house technical staff are not a "nice-to-have" luxury but a necessity if museums and institutions hope to meet the public's expectations around digital technologies. As our experience building and iterating on the SkyTerrace interactive installation demonstrates, a dedicated technical staff can execute projects faster and more cheaply than third-party vendors or consultants, and this work can, over time, be leveraged to develop ever-more sophisticated and engaging projects. ▮

1 "Mills Field and the San Francisco Airport," Mills Field, SFO Museum, accessed December 12, 2022, https://www.sfomuseum.org/exhibitions/mills-field-and-san-francisco-airport.

2 Aaron Cope, "Maps (and map tiles) at SFO Museum," Mills Field, SFO Museum blog, July 31, 2018, https://millsfield.sfomuseum.org/blog/2018/07/31/maps/.

3 See, "Maps of SFO in Time," SFO Museum, accessed December 12, 2022, https://millsfield.sfomuseum.org/map.

4 Originally slated to open in February 2020, the SkyTerrace was delayed due to the COVID-19 pandemic.

5 These costs reflect 2019 figures. In 2022, equivalent or superior iPads are available for less, which would bring the cost today closer to $3,000.

6 Both Electron and Cordova are open-source application frameworks, with active developer communities, written using standard web technologies (e.g., HTML, JavaScript, and CSS). These applications are then compiled into native code, targeting all the major desktop and mobile operating systems. For more on these platforms, see "Build cross-platform desktop apps with JavaScript, HTML, and CSS," Electron, accessed December 12, 2022, https://www.electronjs.org/ and "Apache Cordova," accessed December 12, 2022, https://cordova.apache.org/.

7 Specifically, it is the W3C Presentation API which has yet to be finalized. See, "Presentation API: W3C Candidate Recommendation Draft," W3.org, June 2, 2022, https://www.w3.org/TR/presentation-api/.

8 "WKWebView: An object that displays interactive web content, such as for an in-app browser," Apple Developer, accessed December 12, 2022, https://developer.apple.com/documentation/webkit/wkwebview.

9 That engine, called WebKit, is the underlying technology that drives the Safari web browser. See, "A fast, open source web browser engine," WebKit, accessed December 12, 2022, https://webkit.org/.

10 For more on bidirectional channels, see "The WebSocket API (WebSockets)," mdn web docs_, accessed December 12, 2022, https://developer.mozilla.org/en-US/docs/Web/API/WebSockets_API.

11 For more on unidirectional channels, see "Server-sent events," mdn web docs_, accessed December 12, 2022, https://developer.mozilla.org/en-US/docs/Web/API/Server-sent_events.

12 The application also spent the months between March 2020 and June 2021 running unattended. During this time, due to COVID-19 restrictions, SFO Museum worked offsite. To see both the hardware and software operating without incident upon our return increased our confidence in deploying both in the airport terminal environment.

13 We did, however, need to address bugs introduced by a regular update to Apple's operating system. Between the release of iOS 15 and 15.5 the SkyTerrace map application was unable to render the coastline of the San Francisco Bay Area due to bugs that were introduced to the underlying graphics libraries in the operating system. The coastline is an important graphic element in the installation, so these bugs required developing and deploying an alternate approach. This was time we had to spend not to add new features or to address problems in our code but to solve for a breaking change in the platform. While it is difficult to quantify the costs of vendor changes such as this, they are non-zero and should be budgeted for in any similar project. For more on this issue, see "Safari crashes when GPU Process: Canvas Rendering is enabled with large paths," WebKit Bugzilla, accessed December 12, 2022, https://bugs.webkit.org/show_bug.cgi?id=231157#c6; and Aaron Cope, "Serving map tiles to yourself using Protomaps and iOS," Mills Field, SFO Museum blog, March 30, 2022, https://millsfield.sfomuseum.org/blog/2022/03/30/swifter-protomaps/.

14 We do this in two main places: the SFO Museum blog and on the museum's page on GitHub.com. To access our publications on GitHub see, "San Francisco International Airport Museum: Repositories," GitHub.com, accessed January 13, 2023, https://github.com/orgs/sfomuseum/repositories. For detailed blog posts related to software development related to the map installation, see "Weblog," Mills Field, SFO Museum, accessed January 23, 2023, https://millsfield.sfomuseum.org/blog/.

15 This author believes that an important part of making this possible is to be deliberate about sharing the smaller tools and techniques that make up a project, and not just the finished applications themselves, which are tailor-fit to the organization deploying them. While every museum has its own unique circumstances and challenges developing and deploying digital experiences, it is important that we take the time to identify and shares those pieces of a larger puzzle that are common across the cultural heritage sector.