Envisioning Future Applications for Simtable Technologies

An Interactive Qualifying Project (IQP) submitted to the faculty of Worcester Polytechnic Institute (WPI) to fulfill a requirement in pursuit of a Degree of Bachelor of Science by undergraduate students

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Abstract

Simtable wishes to build upon their Simtable environment with two new technologies: Realtime Earth and AnySurface. Realtime Earth allows users to share camera and location data while AnySurface leverages cameras and projections to make surfaces into interactive displays. Our team sketched ideas for combinations of the software and received feedback from experts. Our team then produced two video mockups and a third script with accompanying materials, combining Realtime Earth and AnySurface: a Home OS that connects a user to their relatives, friends, and work all in their home; an Incident Command OS that streamlines the transmission of information between civilians and first responders during a fire; and an interactive system that allows users to interact with the environment.

Acknowledgements

We would like to acknowledge the individuals who have made this project possible with their support and guidance. We would like to give thanks to the individuals who allowed us to interview them including Darryl Jones, the Fire Chief of South Carolina; Anthony Schultz from ESRI; Jack McCall from Lindsey; Katie Withnall and Dana Heusinkveld from the New Mexico Forest and Watershed Restoration Institute; and Stephen Graydon from the Terra Fuego Resource Foundation. We would also like to acknowledge the employees at Simtable who not only permitted us to interview them, but also gave helpful feedback about our project while we took steps to complete it which includes Kasra Manavi, Joshua Thorp, and Cody Smith. Thank you to our sponsor, Stephen Guerin, CEO of Simtable, who has given important feedback and helped us generate ideas at every stage of this project, and thank you to our liaison, Leila Al-Hemali, who was always open to communication with us and provided the necessary feedback that we needed to improve our project. Finally, thank you to our advisors, Dominic Golding and Jeffrey Solomon, who have supported us throughout this project and been advocates for us when necessary. This project would not have been possible without the efforts of these wonderful people, and we are thankful that they have worked with us to ensure this project would be a success.

Executive Summary

In the U.S., 847 individuals from 1901 to 2017 died from wildfires, including 748 civilians and 99 firefighters (Haynes et al. 2020). The growing extent and damage caused by wildfires is an unfortunate consequence of human-induced climate change (IPCC, 2021, 9). While many factors contribute to wildfires, including poor forest management practices over the past decades, climate change has exacerbated the extent of wildfires in the U.S. (Vose et al., 2018) estimated that the spending on wildfire response increased from $809 million in 2000 to $2.1 billion in 2016 (Vose et al., 2018). The property damage due to wildfires in the Wildland Urban Interface (WUI) reached $648 million in 2021 (NFPA 2021-b). Climate change drives a troubling rise in wildfires, which brings forth massive response and property damage. State and federal agencies responsible for preventing and fighting wildfires are under constant pressure to combat the escalating crisis.

To address the surging demands of emergency response, specifically wildfire response, Santa Fe-based Redfish founded Simtable. Simtable's main product, Sandtable, with the assistance of AnyHazard software, simulates wildfires and other emergency scenarios. This simulation tool allows first responders and community leaders to train and respond to realistic disaster situations (Simtable -b). Related Simtable software, AnySurface and Realtime Earth, expand on Simtable's simulation environment. AnySurface allows multiple users to control and interact with multiple screens in a room. With Realtime Earth users stream their location and camera data to inform others of their current situation.

Simtable tasked our team with developing one or more mock-ups of applications utilizing AnySurface and Realtime Earth for collaboration, emergency response, education, and sousveillance. We achieved this goal by completing the following:

- Objective 1: Assess the origins, development, current state, and capabilities of AnyHazard, AnySurface, and Realtime Earth.
- Objective 2: Evaluate possible applications for AnyHazard, AnySurface, and Realtime Earth software combinations.
- Objective 3: Build and evaluate mockups of the most promising applications.

Our team created mockups that utilized both the features of AnySurface and Realtime Earth in an effective and useful manner. We learned about AnySurface and Realtime Earth software while in Santa Fe, which built on our background research. We produced mockups combining the features of AnySurface and Realtime Earth and solicited feedback from experts on them. We presented our mockups displaying the direction we believed AnySurface and Realtime Earth could go.

While the technologies Realtime Earth and AnySurface are still in development to improve upon the Simtable System, they have the potential for innovative and practical uses. After brainstorming, sketching ideas, and producing two mockup videos and a script with accompanying materials, we have developed two sets of conclusions related to each mockup. The first mockup details a Home Operating System that integrates spaces (projector-camera pairs), Realtime Earth camera feeds, one-directional information streams, and phone controls into the user's daily life at home and work. We conclude that:

(1) AnySurface could be designed as an interactive home/room operating system.

(2) Controls to AnySurface may be touch-sensitive or via a phone.

(3) Acequia(s) control data flow in a user's system and between users.

(4) Entering an Acequia happens through QR code scanning plus manager/group approval.

(5) A major use case for this system is establishing a connection to an immobile individual, such as those in a hospice care setting.

We present five recommendations for how Simtable can pursue these conclusions to fully integrate AnySurface and Realtime Earth in home and work environments for collaboration and communication.

1. We recommend that Simtable expand on its current AnySurface Software solutions and produce a preliminary environment for running and controlling them in the browser. This would entail constructing menus and controls for an education-based system (building on Electric Field Hockey and Ants) that utilizes the duality of cameras and projectors. An additional interface for controlling AnySurface from a phone would be necessary for both setup and low-level control of spaces. From there, the system could be expanded to include controls via objects in a room tracked by cameras. Once this system is built with quality controls and interactive apps, it could be expanded with basic editing tools to mimic existing software such as Word and PowerPoint.
2. We recommend a system like AnyHazard's 'clipboard' be developed to serve as the control panel for an AnySurface System. The control panel will open a user's Acequia(s)

to other users, set up and manage projector-camera spaces as well as Realtime Earth camera feeds. The control panel also allows the user to 'throw' a screen to a space and have interactions with the space. The space itself should be controlled via gestures/touch, in addition to the control panel. Essentially, a phone would supplant the current laser pointer-based interaction, and gestures would be added so a user would not need to have their phone with them constantly.

3. We recommend the entire system be constructed around the Acequia concept. All data for a specific user, shared data, and relationships between users will be stored in the Acequia. We recommend two Acequia systems: a manager system, and a democratic system. A single user, an educator, or a corporate environment would utilize a manager system with central power to one or a set of users. A group of friends sharing media or images would have a democratic system with a voting mechanism for both adding or removing members and changing permissions. The Acequia should also storeroom configuration data so a set of spaces could easily be reestablished either in person or remotely.
4. To maintain security over an Acequia like a collaborative space within a company, a QR code controlled by a manager could be displayed to allow an individual to 'enter' the Acequia. A QR code could be used to unlock doors and grant access to certain files or spaces. The QR code scanning would be integrated within the AnySurface control panel on the User's devices.
5. We recommend building this system with Asymmetric flows of data. This means that once one user gives permission, a second user can provide live streams of data, and flows of pictures or change the conditions in the first user's room. We envision this configuration for a hospice care patient, or an immobile individual (the first user) so they can have a connection with their family (the second user). Realtime Earth cameras controlled by a family member could stream feeds of grandchildren playing to an elderly relative.

The second mockup, due to time constraints and sponsor recommendations, was never filmed. However, a script and accompanying materials were created and these demonstrated a Fire Response system integrating Realtime Earth, AnySurface, and AnyHazard. We conclude that:

1. Realtime Earth could be used for surveying/data collection prior to fire.

2. Different *Acequias* could control data flows to insurance, emergency preparation, and homeowners/neighborhoods.
3. Realtime Earth could improve communication during an emergency with location-based collective intelligence tools.
4. Realtime Earth could improve simulation accuracy during an emergency through live data streams of a fire.

We present five recommendations for how Simtable can pursue these conclusions to fully integrate AnySurface and Realtime Earth in a fire response environment.

1. We recommend Simtable further develop a Realtime Earth-based solution to collect camera data on users' property to survey fire risks and maintain security. This process can include a fire risk assessment to prompt the user to mitigate fire risks around their house.
2. We recommend that Simtable utilizes the *Acequia* concept to control fire risk data collected through Realtime Earth. Insurance agencies could provide quotes based on information gained from a client's *Acequia.* The clients could negotiate better rates by reducing fire risk to their property. Emergency protocol planners could have access to homeowners' *Acequias* to create more accurate simulations that better inform decisions during a disaster.
3. We recommend that Simtable explore the use of Realtime Earth to improve communication between first responders and civilians during fires. Users could stream location and camera data to first responders for a limited time. ..This information could be integrated into Simtable operation to synergize the flow of simulations and live data during a fire. Additionally, civilians in a neighborhood could share data to better prepare themselves in the event that there is an emergency. For example, preparations can be made if someone requires mobility assistance to extricate a home.
4. We recommend Simtable leverage data collected via Realtime Earth to perform fire simulations in times of emergency. Through the combination of prior and current information, emergency responders could decide whether an area should be saved or evacuated during a fire.

Authorship

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Introduction

In the U.S., 847 individuals from 1901 to 2017 died from wildfires, including 748 civilians and 99 firefighters (Haynes et al. 2020). The growing extent and damage caused by wildfires is an unfortunate consequence of human-induced climate change (IPCC, 2021, 9). While many factors contribute to wildfires, including poor forest management practices over the past decades, climate change has exacerbated the extent of wildfires in the U.S. (Vose et al., 2018). It is estimated that the spending on wildfire response increased from $809 million in 2000 to $2.1 billion in 2016 (Vose et al., 2018). The property damage due to wildfires in the Wildland Urban Interface (WUI) reached $648 million in 2021 (NFPA 2021-b). Climate change drives a troubling rise in wildfires, which brings forth massive response and property damage. State and federal agencies responsible for preventing and fighting wildfires are under constant pressure to combat the escalating crisis.

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To assess AnySurface and Realtime Earth, we interviewed Simtable employees, read pertinent Simtable documentation, and viewed demonstrations of the technology. We devised combinations of Realtime Earth and AnySurface via sketches and storyboards. At the same time, we evaluated these ideas as well as AnySurface and Realtime Earth applications by conducting interviews with experts. Using this information, we developed mockups using Miro, OpenShot Video Editor, and Google Slides. We solicited feedback on these mockups and presented them to our sponsor as well as any additional findings related to the direction of AnySurface and Realtime Earth.

Chapter 1: Background

In this chapter, we overview the methods currently deployed to fight wildfires and describe their successes and shortcomings. We describe, in detail, AnyHazard, Simtable's simulation software, a technology that is widely used by federal, state, and local government agencies in the US and abroad. Simtables are used to make current wildfire fighting in the face of climate change more effective. We conclude with a description of related Simtable software, AnySurface and Realtime Earth, as well as their competition, which improve communication and collaboration desperately needed to fight increasingly dangerous and taxing wildfires.

1.1 Climate Change as a Driving Force for Natural Disasters

Greenhouse gases released into the atmosphere by humans in the industrial era have drastically changed Earth's climate (Intergovernmental Panel on Climate Change (IPCC), 2021, p. 4). Figure 1 shows that human activities have resulted in a significant increase in average global surface temperatures, especially since the 1950's. According to the IPCC, the average temperatures in the decade from 2011 to 2020 exceed that of any time in the last 125,000 years (IPCC, 2021, p. 8). This increase in temperature fuels more frequent, severe, and extensive natural disasters (IPCC, 2021, p. 8). The IPCC "observed [increases] in [extreme weather events] such as heatwaves, heavy precipitation, droughts, and tropical cyclones," due to human-induced climate change (IPCC, 2021, 8). Figure 2 illustrates that the number of loss events resulting from natural hazards globally has increased steadily since the 1980s and this increase is attributed to the changing climate. While hydrological and meteorological events have seen the greatest increases during this period, wildfires heightened by human activity have also been on the rise.

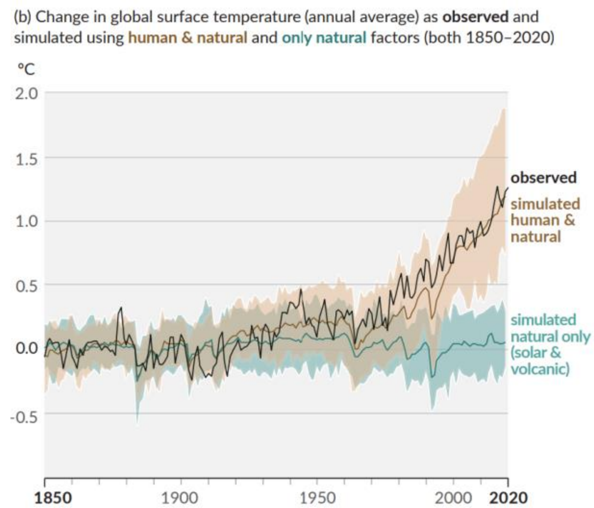


Figure 1: Annual Average Global Surface Temperature Changes Due to Human Action (IPCC 2023)

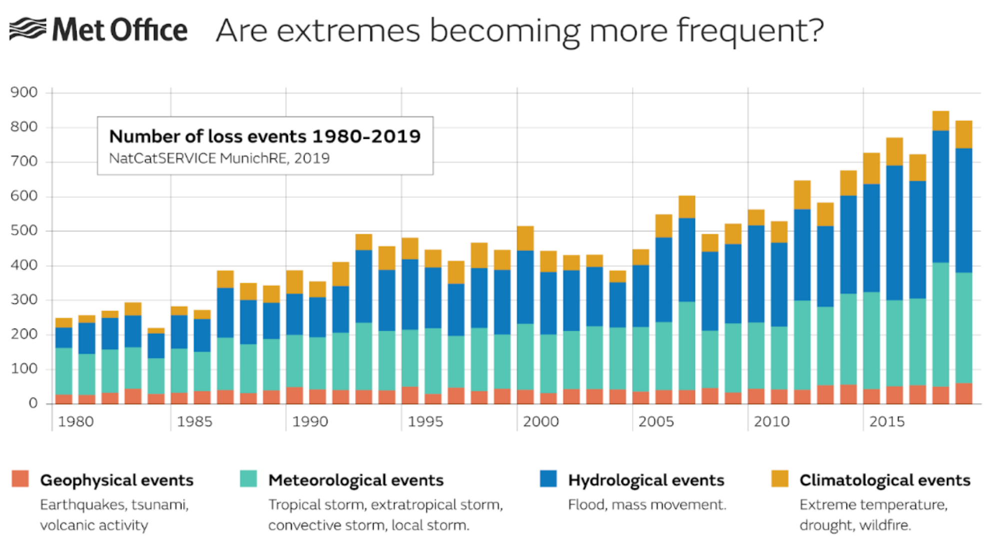


Figure 2: Worldwide Growth of Natural Disasters over Time (Met Office 2023)

The growth in the extent and damage caused by wildfires is an unfortunate consequence of human-caused climate change (IPCC, 2021, 9). While many factors contribute to wildfires, including poor forest management practices over the past decades, climate changes have exacerbated the extent of wildfires in the U.S. Figure 3, for example, shows the area burned by wildfires in the U.S. increased dramatically from less than five million acres in 1985 to a peak of 9 million acres in 2020 (Environmental Protection Agency 2022-b). California in particular saw a fivefold increase in the area burned per year from 1972 to 2018 (Williams et al., 2019, p. 1). It is estimated that spending on wildfire response increased from $809 million in 2000 to $2.1 billion in 2016 (Vose et al., 2018, p. 236). Sadly, wildfires have killed 846 individuals from 1901 to 2017, including 748 civilians and 99 firefighters (Haynes et al. 2020, p. 3). Recent fires have become more destructive and dangerous. For example, 'Camp Fire' in 2018 claimed 85 lives and is considered the most destructive wildfire in California history. Seven of the top ten most destructive wildfires in California history (accounting for burn area, structures destroyed, and deaths), occurred after 2014 (Insurance Information Institute, 2022). The property damage due to wildfires in the Wildland Urban Interface (WUI) in the U.S. reached $648 million in 2021 (NFPA 2021-b). Climate change drives a troubling growth in the extent of wildfires, massive property damage and response costs, and a growing capacity for wildfires to destroy life. State and federal agencies responsible for preventing and fighting wildfires are under constant pressure to meet the escalating crisis.

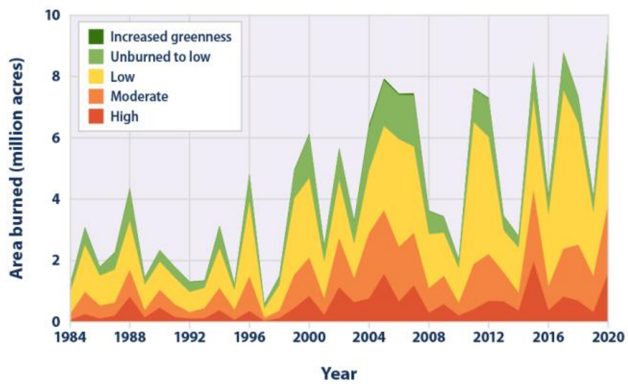


Figure 3: Area in the U.S. Burned by Wildfires, 1984-2020 (Environmental Protection Agency 2022-a)

1.2 Emergency Preparedness

In this section, we outline the process of preparing for wildfires through training firefighters and forest management. We review the current U.S. standards for firefighter training, including their successes and drawbacks. We examine the U.S. guidelines for wildfire preparedness in both forests and wildland-urban interfaces. Because wildfires are growing in size, ferocity, and duration, we also critically examine firefighter training and preparedness to reveal their strengths and weaknesses.

With the rise in property damages and an increase in loss of life due to wildfires, the National Fire Prevention Association (NFPA) conducted its fifth survey to measure the preparedness and training of fire departments across the U.S. (NFPA 2021-a). The survey found that only 30% of all fire departments could deploy 100% of their crews with wildland fire gear (see Table 1). The survey also found that 78% of departments that fight wildfires require more training to adequately handle fires. Specifically, departments lack training in wildland-urban interface (WUI) fires. In fact, only 47% of the departments surveyed claimed they had the training and equipment necessary to handle a wildfire of 10 acres or more (NFPA 2021-a). These statistics reveal a strong need for better training and coordination between departments to share resources for fighting wildfires.

Proportion of emergency responders with protective clothing	**Percent of Fire Departments**
All (100%)	30%
Most (76-99%)	12%
Many (51-75%)	7%
Some (26-50%)	8%
Few (1-25%)	11%
None (0%)	20%
Department does not perform wildland firefighting	13%

Table 1: Proportion of fire departments providing wildland fire personal protective clothing? (NFPA 2021-a)

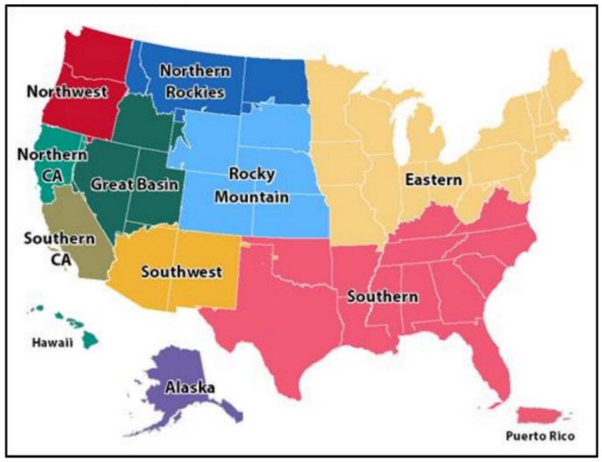
In addition to focusing on training and equipment, the Forestry Service, a branch of the USDA, constructed a 10-year strategy for battling wildfires that focused on protecting communities by 'fortifying' U.S. forests (USDA n.d.). The strategy requires more than 50 million acres of controlled burns to remove downed pine needles and other forest fuels to reduce the likelihood of severe fires (USDA 2022). The report promotes ‘community wildfire protection plans’ to harden houses from wildfires in WUI areas so that citizens can learn to live with wildfires safely (USDA 2022). The trouble is that climate change creates drier conditions than the ones experienced when prescribed burn protocols were written (Westervelt 2022). Prescribed burns, while possibly the most effective tool to prevent large wildfires, become more dangerous as the planet warms. In turn, prescribed burns are increasingly likely to get out of control (Westervelt 2022).

Fire departments responsible for fighting wildfires across the U.S. appear woefully ill-equipped and unprepared to handle the expected growth of the extent and severity of wildfires. Prescribed burns are an effective tool for preventing wildfires, but firefighters desire a coordinated system that correctly models dry conditions to mitigate the risk of losing control of prescribed burns due to climate change.

1.3 Emergency Response

Wildfire response is a demanding task from all stakeholders: ground personnel, coordinators, government officials, and communities in danger (Federal Interagency Wildfire Response Framework 2023). The U.S. wildfire response breaks down into two categories: federal land fires and nonfederal land fires. The origin of a fire defines which party, state or federal, is responsible for fire suppression. However, the on-the-ground circumstances and contracts can change this. Government organizations mobilize resources to fight wildfires in a bottom-up fashion from local to state, then federal coordination. Firefighters with command centers, heavy equipment, aerial vehicles, and support, like showers and food, are resources deployed to fight fires in the U.S.. Local response declares the wildfire and deploys initial resources; if necessary, local government moves resource requests to Geographic Area Coordination Centers (GACC) which coordinates resource allocation within regions seen in Figure 4. Once the GACC runs out of resources, national aid is called for which can even draw upon military resources. All stakeholders require this system to work as well as possible to correctly allocate resources in a timely fashion (Federal Interagency Wildfire Response Framework 2023).

Figure 1. Geographic Area Coordination Centers



Source: CRS, using data from the National Interagency Fire Center.

Figure 4: GACC Distribution in U.S. (Federal Interagency Wildfire Response Framework 2023)

The ground response to a wildfire is run by the Incident Command System (ICS) (National Parks Service n.d.). ICS manages a wildland fire from beginning to end, controlling personnel, facilities, equipment, and communications. The ICS consists of command, operations, planning, logistics, and financial structures. The command structure of the ICS defines the strategy for combating each wildfire while prioritizing firefighter safety. The operations structure executes the strategy command sets by creating an action plan and supervising all Branch/Division/Group/ and Air resources. The planning structure collects and evaluates data to prepare for the Operation’s action plan; this involves predicting incident events and disseminating information pertinent to the action plan. The logistics division supplies the resources to support the tactical operations for the incident including facilities, transportation, supplies, equipment management, as well as food and medical services. For large-scale responses, the Financial Administration documents fiscal information (National Parks Administration n.d.). The coordination for this system demands quality communication and up-to-date information to properly request and deploy resources (National Parks Administration n.d.).

A non-partisan commission reporting to Congress found that the current arrangement for fighting fires suffers from inadequate coordination, poor resource allocation, limited availability of resources, and inappropriate financial decisions (Federal Interagency Wildfire Response

Framework 2023). With many fires requiring large responses, it is critical to get all the stakeholders, be it local, state, or federal officials to coordinate directly, not just through a regional system like GACC. This leaves room for advancements in the collaboration and logistics systems that are currently deployed which, as presented to Congress, lack effectiveness (Federal Interagency Wildfire Response Framework 2023).

Addressing the wildfire response and preparedness system's flaws is something various companies and technologies seek to do. Simtable is one of those technologies designed to improve preparedness and response through staff training using simulations.

1.4 History and Development of Simtable

This subsection details the progression of the Simtable technology as a method for emergency preparedness, emergency response, and community outreach (Simtable n.d.-b). Beginning with a description of agent-based simulation, the section details the initial goals of Simtable simulation. We assess the additional capabilities of Simtables to characterize the current state of Simtable technology. We conclude this section by discussing the limits of Simtable technology; emergency preparedness demands more from Simtable.

According to Columbia Medical Center, agent-based simulations "study the interactions between people, things, places, and time," (Columbia University Medical Center 2022). Individual agents are given certain attributes that define how agents interact with each other to produce a stochastic model. Experiments that would be immoral to perform in the real world or observations that cannot be replicated can be explored by complex systems implemented with agent-based modeling (Columbia University Medical Center 2022). The Santa Fe Institute, the first research institution with a sole focus on 'complexity science,' defines a complex system as, "any system in which many agents interact and adapt to one another and their environments" (Santa Fe Institute n.d.). Examples of complex systems include civilizations, cities, the internet, economies, ecosystems, and the nervous system. In these complex systems, it is impossible to untangle causes and effects. Simulations of these systems demonstrate their emergent properties (Taylor Pearson n.d.). For instance, a property of wildfires is that the relationship between the burn extent of a wildfire and the density of burnable material follows a specific mathematical equation (Personal Communication, Stephen Guerin, Simtable CEO, October 25th, 2023). Our sponsor, Simtable, leverages agent-based models to demonstrate these emergent properties to improve emergency preparedness, wildfire response, education, and defense (Santa Fe Institute n.d.) (Simtable n.d.-b). n.d.-b).

Founded by Stephen Guerin, Simtable represents a cutting-edge technology for agent-based modeling, data visualization, and human-computer interaction (Simtable n.d.-a). To build on sand table training, which is a common method for wildfire response training, Simtable produces an interactive Sandtable that projects geospatial data and simulations using AnyHazard software onto the sand (Simtable n.d.-b). In 2009, Simtable began with a focus on training tools for firefighting academies (Guerin 2010). As seen in Figure 5, Simtable's initial product was a physical sandbox with both a camera and projector pointed at it; the projector displayed the simulation while the camera captured human interaction with the table (Guerin 2010). The camera and projector work synergistically to create 'structured light' scans to correlate camera and projector pixels and determine the height of the sand at every point on the sand table (Guerin 2010). With 'structured light,' a Simtable user can precisely shape any terrain to match the topography of a landscape for a simulation (Guerin 2010). As shown in Figure 6, a person can move sand into the red areas that indicate higher ground and remove sand from blue areas which represent lower land. Furthermore, the platform was built to interact with laser pointers with plans to release a gesture recognition system (Guerin 2010). The foundation for Simtable technology established here will be examined further with its individual applications in the next section.

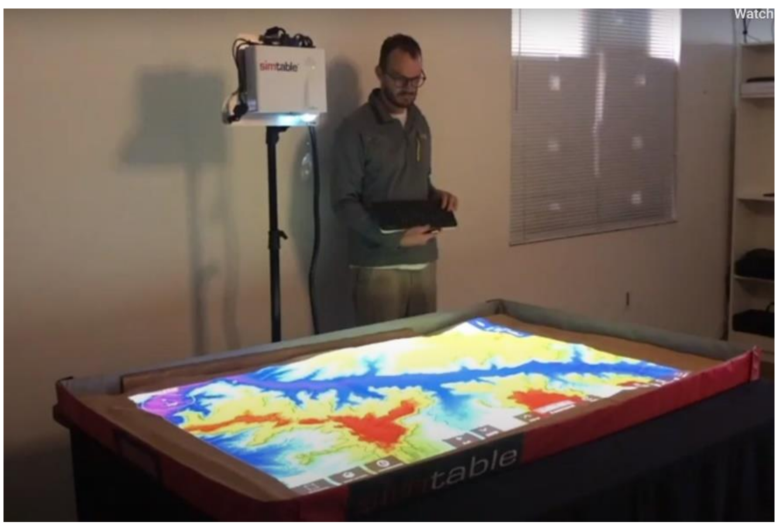


Figure 5: Simtable Sandtable with Projector and Camera (Simtable n.d.-a)

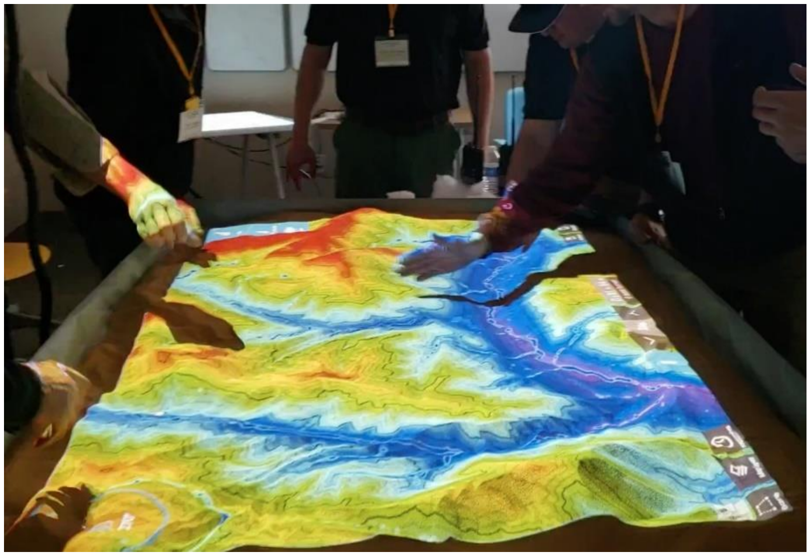


Figure 6: Shaping the Topography of a Simtable (Simtable n.d.-a)

1.4.1 Simtable Simulation Applications

Using custom simulation and terrain features, firefighters can train for and respond to wildfires with Simtable (Simtable n.d.-i). Simulations of wildfires (created using the AnyHazard software) for training or response use wind speed and direction, terrain, and slope to create realistic, interactive experiences. Fueled by customer data or publicly available GIS data, various maps and topographies can be used to simulate current or past fires. Simtables allow the user to differentiate between hand-cut firebreak lines and bulldozer firebreak lines, including rain as well as other options. Simtable offers multi-user cloud-based solutions that allow for a distributed command setup (Simtable n.d.-i). The holistic, precise environment for simulating wildfires provided by Simtable is an effective tool for fighting wildfires.

Simtable can also be used to educate community members about the factors that shape wildfires and appropriate emergency responses to take under different scenarios (Simtable n.d.-h). Easy operation of the system using a laser pointer allows citizens to perform a simulation of their neighborhood during a wildfire as seen in Figure 7. Simtable offers other modules for educating the public about managing wildfire fuel, evacuation planning, and population modeling for vehicles. Simtable provides other education modules that focus on academics and inspiring STEM participation rather than promoting public awareness (Simtable n.d.-d). Simulations of watersheds, erosion, post-wildfire forest restoration, and population movement give students a way to understand the world around them through interactive experimentation. Students can use Simtable to write their own simulations which, according to Simtable CEO, Stephen Guerin, “[you] would [otherwise] have to be in graduate school with some kind of complicated mathematics to write” (simtablevideos 2015). Thus, Simtable provides an effective means for instructing the public on emergency management and instructing students on small to large-scale geospatial topics. Simtable created and implemented a four-week summer education program based on the Simtable technology. The program focused on the geospatial representation of data, agent-based modeling, and drone-land mapping (Personal Communication, Kasra Manavi, Simtable Head of Research, October 25th, 2023).

Figure 7: Students Interacting with a Simulation of their Neighborhood with Simtable (Simtable n.d.-d)

Simtable developed a series of other interactive applications that enhance traditional sand table exercises present in defense training, flood management, and chemical handling. Digital maps can be projected onto 3D cityscapes or sand tables for military and police applications (Simtable n.d.-c). Satellite data incorporated into defense or police simulations provides a more realistic experience (Simtable n.d.-c). The water module provided by Simtable simulates storms, watersheds, and dam breach flooding seen in Figure 8 (Simtable n.d.-e). Burn scars enhance flood modeling as burn scars can drastically change the behavior of water flow during a rainstorm. Real-time data from real-world sensors can provide precise analysis in water-based simulations. Figure 9 demonstrates the Hazmat Module for Simtable simulating a smoke plume which can originate from chemical spills or burns interacting with terrain for strategic resource management (Simtable n.d.-e).

Figure 8: Flood Simulation with Simtable (simtablevideos 2022)

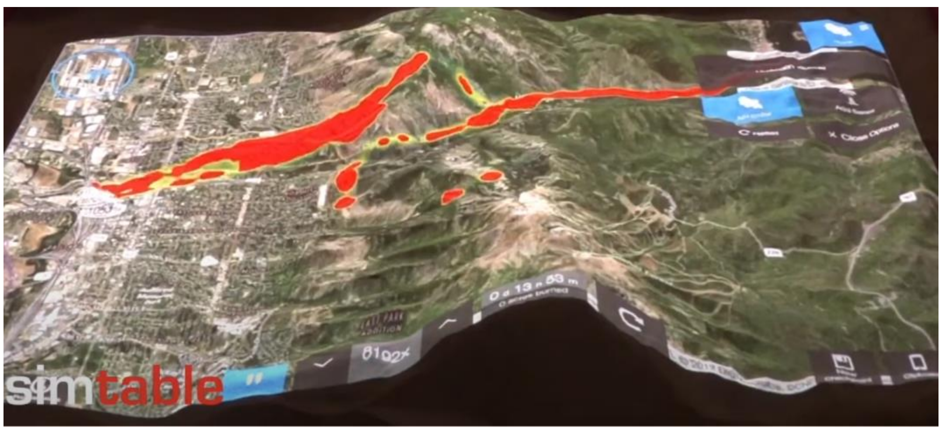


Figure 9: Simtable Smoke Plume Simulation with Smoke Cresting a Mountain due to Wind (simtablevideos 2022)

The tools for wildfire management, community outreach and education, and emergency management clearly provide benefits to stakeholders. However, they are limited in that collaboration occurs around one surface, the Simtable. Stephen Guerin recognized this limitation and pushed the operation of Simtable into the browser to allow for multiple participants (simtablevideos 2015). Simtable creates a powerful collaborative environment for many scenarios, but it is not without competition. Similar products to Simtable will be examined next.

1.4.2 Clients and Competition

Simtable is a small company with under 20 employees that has been in business for over a decade and has an annual revenue of about 5 million USD. In this section, we will look into Simtable's current customer base and competitors of different aspects of Simtable.

As shown in Figure 10, most of Simtable's clientele is based in the United States, with a sparse number located in other countries such as Italy, Spain, and Australia. Due to the simplicity and ease of setting up and conducting simulations, Simtable's customers in the United States range from federal agencies, such as the United States Forest Service, the United States Bureau of Land Management, and the United States Department of Agriculture, to state and county agencies, including California Department of Forestry and Fire Department, Pima County, and Santa Fe County, to educational institutions, including Harvard University and California Polytechnic State University (Simtable n.d.-f). Some of the foreign clients that have installations of Simtable include VeniceTable, where they collect traffic information for authorities to implement canal regulations (Venicetable n.d.), and the Hunter Joint Organization, where they run hazard simulations to improve local preparedness and response in case of an actual hazard (Simtables - HJO n.d.).

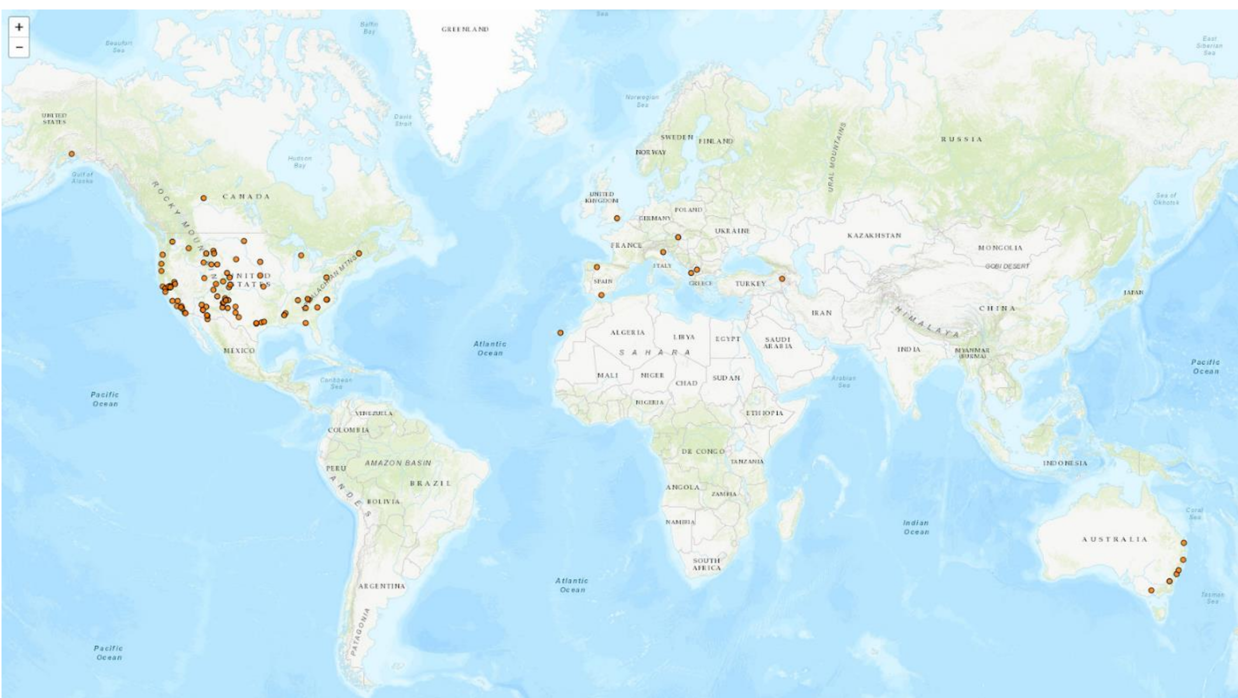


Figure 10: Location of Simtable Customers (Simtable n.d.-f)

There is no analogous augmented reality sandbox that has AnyHazard functionality like Simtable, however, there are some products that exhibit similar, yet less functionality. Numerous wildfire simulation programs are currently in use globally, such as Prometheus, developed by the Canadian Interagency Forest Fire Center (Prometheus 2023), FlamMap, developed by the U.S. Forest Service (Flammap 2022), and WRF-Fire, developed by the National Center for Atmospheric Research and the National Oceanic and Atmospheric Administration (Lai et al. 2019). There are also many augmented reality sandboxes, such as TopoBox, iSandBox, and Breeze Creative. While no product can mirror all the functionality provided by Simtable, the product faces several limitations to expansion that we discuss next.

1.4.3 Limitations to Company Expansion

After looking into the competition that Simtable faces, we explored factors that hinder Simtable's expansion opportunities in this section. Some of the main factors are the software, and accessibility of the product.

Simtable uses agent-based modeling for their wildfire simulation, which, according to research by Lee and Ma, is the ideal approach for a wildfire simulation scenario. They argue that the returns from using agent-based modeling outweigh both Huygen's wavelet principle and raster-based modeling, which are the two other approaches used by wildfire simulation software. Prometheus, which is mentioned in the last section, implements the use of Huygens wavelet principle, which is the most realistic approach to wildfire simulation. However, this approach requires immense computational power, which could limit its use in large, complex fires, as well as requiring a much higher budget to execute said programs. In contrast, raster-based simulations, which is the approach taken by FlamMap and WRF-Fire, require less computational power but are less accurate (Lee and Ma 2023). Agent-based modeling seems to be ideal for the purpose that Simtable represents, so why do companies and agencies turn to other software?

The accessibility of Simtable is the main problem. Simtable has multiple components, consisting of sand, a projector, a camera, and a computer. It is inconvenient to transport, since the sand must be stored well so that it will not spill, and electronic devices have to be carefully handled. For other programs, all that is required is a computer, which tends to be abundant. These advantages make the choice clear when choosing between different systems. Simtable produced complementary software packages to expand the collaboration space beyond tabletops. These software packages will be examined in the following section.

1.5 AnySurface and Realtime Earth Enhancing Simtable Technology

In this subsection, we examine the new software packages produced by Simtable, debate the effectiveness of the new software, and describe Simtable's goals for the software's development. While the sources for these emerging technologies are sparse, we assemble the information from available Simtable corporate releases and academic articles. We conclude with potential use cases for the software that has yet to be developed to enhance emergency response.

While the collaboration with the Simtable system occurs around the physical sand table, Stephen Guerin pushed for taking the simulation off the table and onto shared surfaces (Guerin 2017). He also proposed a system that allows policymakers to easily implement models to better manage complex interactions in the real world (Guerin 2017). The realization of these ideas came in the form of AnySurface, a software that allows a user to use a mobile device and projectors to display a screen on one surface and interact with it, and then move the display to another surface Figure 11 (simtablevideos 2015). The software can track objects on the surface and determine elevation changes to better map the projection to the surface. The goal of the software is to make any room truly interactive; doctors can have projections of the vitals of their patients for easier viewing or comprehensively displaying research data (simtablevideos 2015).

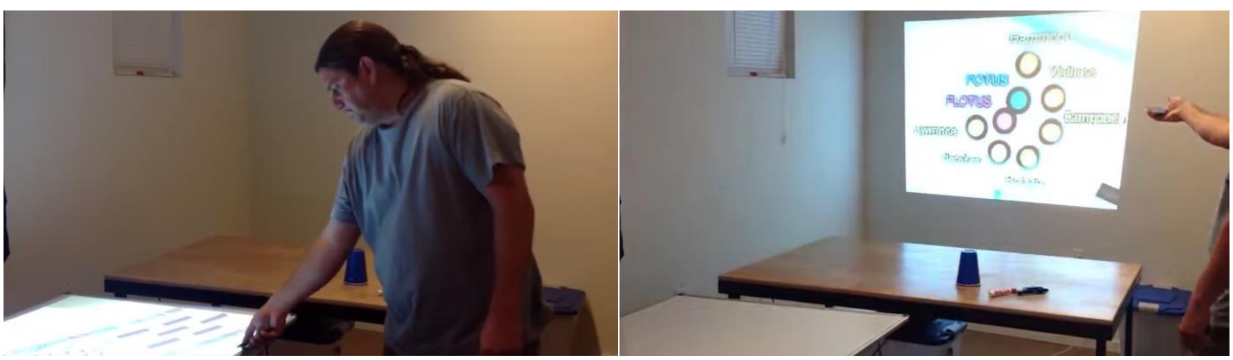


Figure 11: Switching the Location of an AnySurface Screen (simtablevideos 2015)

AnySurface is not without competition: many companies produce devices to make surfaces like whiteboards or televisions interactive. Touchjet Wave deploys an Android operating system on any TV and uses infrared sensing to receive input (Jacobi 2017). Microsoft, Apple, and Google each produce a physical device that plugs into a TV to cast a screen to multiple devices at once (Honorof 2023). AnySurface has an edge over its competition because it can cast multiple screens *and* interact with them. The problem with all screen mirroring systems according to Marshall Honorof, a Senior editor for Tom's Guide, is that they require strong internet connections and are not cross-platform compatible, i.e. Apple vs. Microsoft (Honorof 2023). AnySurface sidesteps the latter issue in that it runs in a browser that requires no permissions from the device itself (simtablevideos 2015). Given that AnySurface has innovations over the current state of the art and access to Simtable's additional software, Realtime Earth, AnySurface's operation is truly unique.

Realtime Earth is software that allows for the real-time display of user-generated images and streams at a certain location (Realtime Earth n.d.). An example of a live stream running in Santa Fe through Realtime Earth is shown in Figure 12. The goal of the software is to implement sousveillance: the concept of civilians performing a bottom-up monitoring of society similar to crowdsourcing (Personal Communication, Stephen Guerin, Simtable CEO, September 1st, 2023). Sousveillance is the opposite of traditional top-down surveillance performed by governments or corporations (Thomsen 2019). Through Realtime Earth, individuals can contribute knowledge to each other in real-time to become 'collectively intelligent' (Personal Communication, Stephen Guerin, Simtable CEO, September 1st, 2023). Stephen Guerin described the concept of collective intelligence to the Senate Committee on Energy and Natural Resources Technology Expo (simtablevideos 2019). He showed how images with locations from multiple phones can be stitched together to create a model of a fire to better inform firefighters, seen as in the blue outline in Figure 13. In 2021, WPI students produced a mock-up for a FireTracker utilizing Realtime Earth and collective intelligence to allow communities to track wildfires in real-time (Levin et al. 2021). Using the proposed app, citizens can take pictures of the fire to inform firefighters from additional angles (Levin et al. 2021).

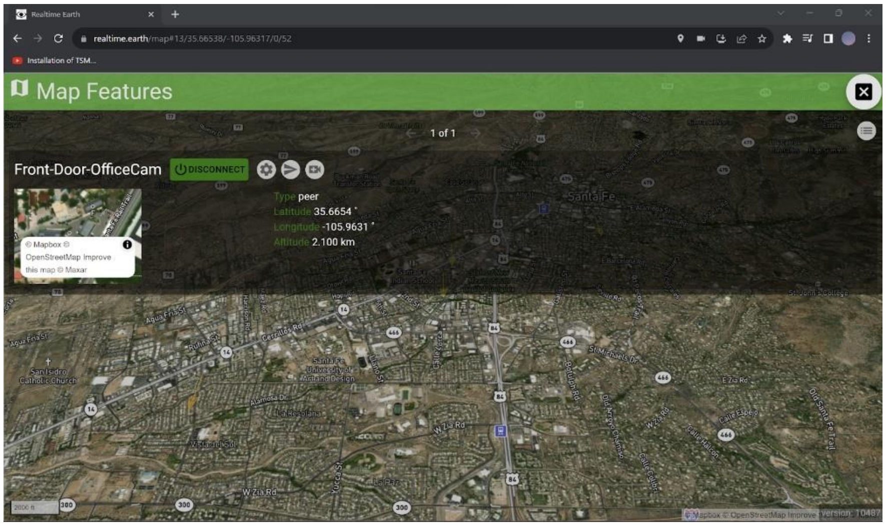


Figure 12: Screenshot of a Livestream from Realtime Earth (Realtime Earth n.d.)

Figure 13: Demonstration of Realtime Earth Concepts to Senate Committee (simtablevideos 2019)

1.6 Privacy and Data Management with Collective Intelligence

One of the major concerns introduced through the use of Realtime Earth is privacy. Due to the easily accessible data in Realtime Earth, the management of privacy and data collection could cause problems for users and discourage them from being interested in using the software. To prevent this, regulations regarding data collection and management should be a priority for Simtable to promote the widespread public use of Realtime Earth.

Realtime Earth allows users to upload their photos of wildfires to the website, and it can be used to determine different aspects such as fire strength and direction. Since the website collects data from the public, we refer to the data collected as commons. Commons is a term used for resources that belong to and can affect a community. Managing commons is essential to create stability in a community. In the case of Realtime Earth, common data shared through the software allows for every user to have access to real-time footage of the other users. Privacy rules can be difficult to establish due to the inability to control who can access what information. Elinor Ostrom, a 2009 Nobel Prize winner "for her analysis of economic governance, especially the commons" (*Nobel Prize Awarded Women,* 2022), published a book named *Governing the Commons.* In the book, she outlined 8 principles for managing commons. Those principles can be categorized into *members* and *management*. Guidelines of members include having clear boundaries of qualification, having the ability to make decisions, and having easy access to conflict resolution. Guidelines for the management of commons include regulations appropriate to the local circumstances, active monitoring by members, sanctions for members who violate rules, recognition by a higher authority as a qualified association, and having necessary connections to other systems (Ostrom, 1990).

Realtime Earth, and to a lesser extent AnySurface, will share information in a framework known as a peer-to-peer network (Zeilemaker et al. 2013). Peer-to-peer networks connect devices over the internet directly to each other rather than through a server that holds data both parties wish to access. The four types of peer-to-peer networks are structured, unstructured, hybrid, and semantic networks. Structured networks ensure all parties know what data all other parties have, resulting in low search latency, but a high cost to keep data up to date. Unstructured networks do not guarantee peers know where all data is stored which increases search time while reducing overhead. The only practical applications of peer-to-peer networks combine the two networks to reduce overhead. The first combination, a hybrid network, contains *super peers* that centralize information about ordinary peers' data but do not hold the data themselves. These *super peers* are like traffic cops, pointing queries to information pertinent to the searches. Semantic peers classify peers with specific interests and connect peers with similar interests when searching. This is different from the hybrid system because there is no centralization. There are numerous privacy concerns with both systems: hybrid systems' super peers centralize information and jettison queries off to implicitly trusted nodes in the network; semantic systems require the specialization of each node to be accessible, which may not be desirable if a particular node contains sensitive information (Zeilemaker et al. 2013).

We acknowledge the privacy concerns of commons, in this case, shared location and camera data, as well as the dissemination of information through a peer-to-peer network. We will need to further investigate the relationship between AnySurface and Realtime Earth to these privacy concerns in Santa Fe.

1.7 Applications of AnySurface and Realtime Earth

Stephen Guerin believes there is an opportunity to innovate at the intersection of AnySurface and Realtime Earth. AnySurface has a competitive edge over other screen mirroring technologies because it can cast multiple screens and interact with them (simtablevideos 2015). Stephen Guerin promoted the idea of collective intelligence, the concept behind Realtime Earth, to the U.S. Senate (simtablevideos 2019). While both technologies are powerful on their own, the combination of them presents immense potential that has yet to be explored.

In December 1999, six Worcester firefighters lost their lives trying to exit a warehouse fire in heavy smoke (Rowe 2009). With this tragedy as motivation, WPI students and professors produced an RF device capable of locating downed firefighters in a burning building (Rowe 2009). The incident commander can view the location of his or her firefighters with a display seen in Figure 14. Possible applications of Realtime Earth and AnySurface could expand this technology to monitoring wildfire firefighters, as opposed to the wildfire, with crowdsourced data using the image stitching technology Stephen Guerin displayed to Congress (simtablevideos 2019). The incident commander could better view their incoming data with AnySurface and view all their firefighters responding to a fire. Combining concepts from the FireTracking app, AnySurface, and current innovations is one avenue for exploration. This is just one example of an atypical use for AnySurface and Realtime Earth. These versatile technologies can be applied to other innovative uses outside of its typical wildfire response and training.

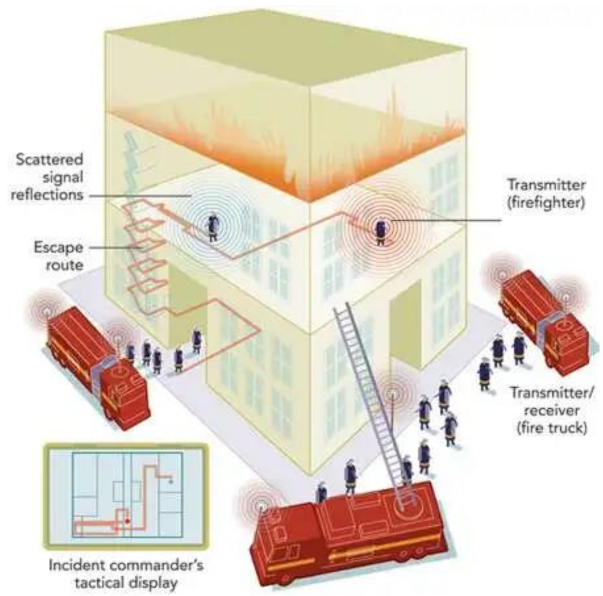


Figure 14: An Incident Commander's Display of a Firefighter's Movement with a Precision Personal Locator (Rowe 2009)

1.8 Conclusion

Simtable currently addresses many problems in emergency management and community outreach. Simtable's product line focuses on combating increasingly dangerous and damaging wildfires fueled by human-caused climate change. While Simtable has success in these areas, our sponsor seeks to expand Redfish's product line by combining or enhancing AnySurface and Realtime Earth. Our project will focus on producing mockups for ideas involving these two technologies, detailed in the next section.

Chapter 2: Methods

The goal of this project was to produce one or more mock-ups of applications utilizing the existing Simtable software packages, AnySurface and Realtime Earth, for collaboration, emergency response, education, and sousveillance. We achieved this goal by completing the following objectives:

1. Assessed the origins, development, current state, and capabilities of AnyHazard, AnySurface and Realtime Earth.
2. Evaluated possible applications for AnyHazard, AnySurface and Realtime Earth software combinations.
3. Built and evaluated mockups of the most promising applications.

The details of our main objectives are shown in Figure 15. We explained the details further in this section. We presented a preliminary timeline for the completion of these tasks and objectives in Figure 16.

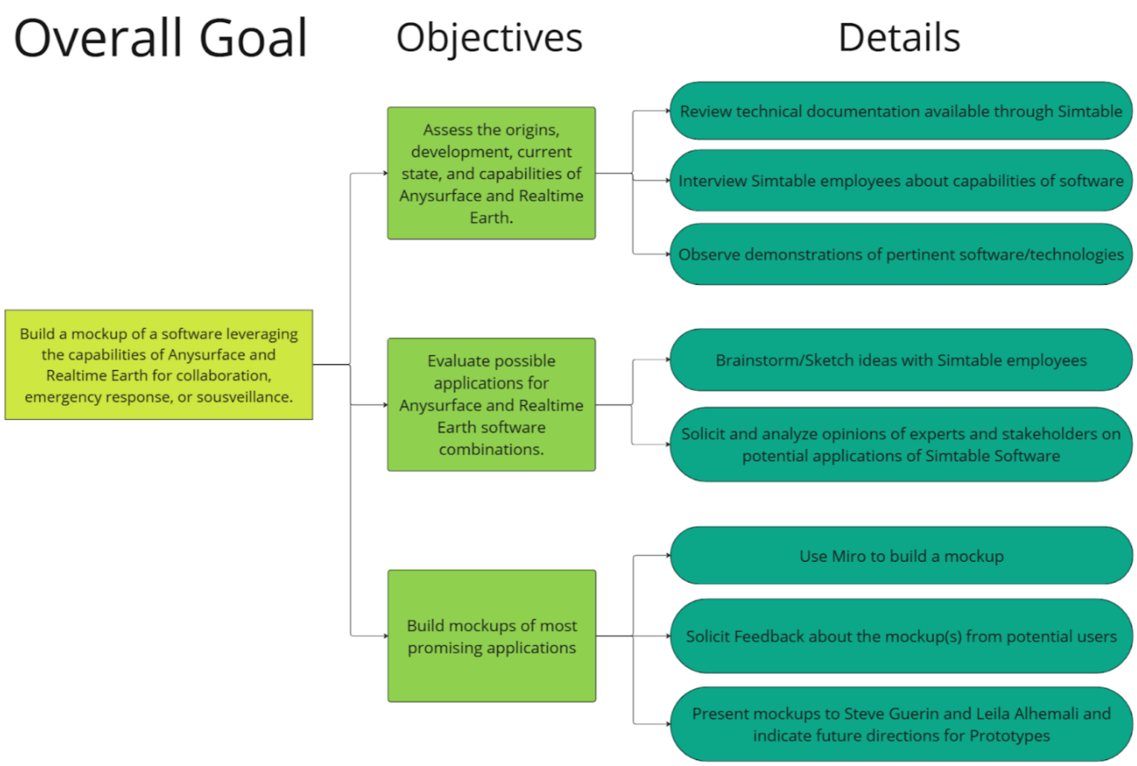


Figure 15: Project Plan

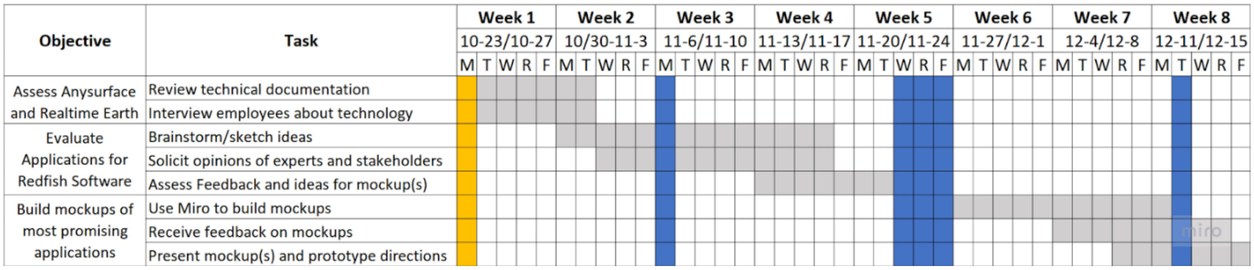


Figure 16: Project Timeline

2.1 Objective 1: Assess the origins, development, current state, and capabilities of AnySurface and Realtime Earth.

We conducted an initial review of the available documentation for Simtable, AnySurface, and Realtime Earth prior to IQP. We bolstered this background research by reviewing additional documentation available to us onsite, interviewing select employees at Simtable, and observing demonstrations of the applications in operation. When onsite, we immediately asked for permission to review any available technical documentation, so we were prepared to discuss Simtable, AnySurface, and Realtime Earth with Simtable employees.

When we began interviewing Simtable employees, we first consulted our sponsor to identify an initial list of Simtable employees and relevant experts that we could talk to about AnySurface and Realtime Earth. Through discussions with Stephen Guerin and Leila Al-Hemali, we ascertained the protocols at Simtable for ensuring the privacy and security of their proprietary technology, as well as the proper channel and email for communication within the company. We obtained permission to meet the interviewees over email prior to the discussion. We used the interview preamble in Appendix 1A to ensure the privacy and safety of our interviewees and security for Simtable technology during this information-gathering phase. To obtain the most thorough review possible of AnySurface and Realtime Earth, we asked for recommendations of others to interview. These interviews ranged from in-person interviews with individual staff members to group discussions among several staff members. We conducted interviews with one member of the team asking questions while another member took notes. Other group members present asked follow-up questions based on the topics in the discussion. We frequently discussed the potential of AnySurface and Realtime Earth with the CEO of Simtable, Stephen Guerin. The list of primary questions for these initial interviews is found in Appendix 2A. We asked unique follow-up questions throughout the interviews to gain a thorough understanding of the technologies. Through these interviews, we gained information about a variety of topics, such as potential extensions of the current Simtable software, possible uses and markets, software limitations, technical documentation, and competing software products. We found it useful to have follow-up conversations with select staff members according to their skills and interests. We conversed multiple times with Stephen Guerin and Leila Al-Hemali to explore our ideas along with their ideas as the ideas evolved during the course in B term.

We observed the capabilities of Simtable, AnySurface, and Realtime Earth remotely, as described in the background section. We also observed the operation of Simtable at Harvard Planetary Laboratory during A-Term. We supplemented this knowledge with hands-on experiences in Santa Fe. Given there was minimal public information on AnySurface and Realtime Earth, in-person demonstrations on both software during our time in Santa Fe were beneficial for finding use cases for the software. Once we were equipped with a thorough understanding of Simtable's software's capabilities at our disposal, we engaged in the next phase of our project, where we started producing mockups.

2.2 Objective 2: Evaluate possible applications for AnySurface and Realtime Earth software combinations.

With a full understanding of AnySurface and Realtime Earth capabilities, we brainstormed possible combinations of the programs and assessed the resulting ideas. Innovation is an iterative process, so our brainstorming and assessment of ideas occurred simultaneously, as indicated by Figure 16. While in this phase of the project, we confirmed our ideas with Stephen Guerin and Leila Al-Hemali to ensure we produced a deliverable aligned with their interests.

Using the information we gathered during meetings with Simtable employees, we developed sketches of potential applications for AnySurface and Realtime Earth. Simtable employs sketches during their brainstorming process; sketches were quick, concise, iterative, and raised questions. We used the Miro online collaboration tool to make our sketches as we received feedback on Simtable tools and our ideas. The path for this project was a broad blue-sky ideation for AnySurface and Realtime Earth combinations. General, abstract sketches and storyboards ensured the broad approach that Stephen Guerin encouraged while maintaining a focus on AnySurface and Realtime Earth capabilities; we indicated the software in use in every frame of our storyboards to ensure clarity. We turned our ideas into sketches and storyboards to serve as drafts for what a potential mockup could include. We kept the sketches and storyboards simple, as they are intended to be a vehicle for understanding the possible directions for this project.

Using the sketches and storyboards, we conveyed our ideas to Simtable employees to solicit feedback; we reached out to employees seeking permission to meet, ensured their privacy and security of Simtable software, and conducted a guided review of our ideas to assess their strengths and weaknesses. Most of our direct feedback on the sketches came from Leila Al-Hemali.

Concurrent with the brainstorming process, our group solicited feedback on Simtable software and our initial ideas through interviews with individuals outside of Simtable. We conducted these more informal interviews with two groups at academic conferences and at Simtable:

- Experts in fields that are closely related to the applications we envisaged initially and mocked up (i.e., Objective 3).
- Current users of Simtable.

We identified subject-area experts in consultation with our sponsor at academic conferences and at the Forest Service. Given this project took multiple paths, we proposed multiple sets of questions about Simtable, AnySurface, and Realtime Earth, found in appendices 3A and 4A. These questions were used in formal interviews at the Simtable headquarters. These questions also served as the basis for informal interviews with conference attendees; however, we asked a variety of questions outside of those in appendices 3A and 4A depending on the individual we talked with.

These interviews, whether informal at a conference, or formal at Simtable, began with the preamble found in Appendix 1A to ensure the safety and security of our interviewees and their employers or sponsors. The proposed interview questions for a wildfire response expert can be found in Appendix 3A. Potential questions for education experts and students can be found in Appendix 4A. All team members were present at every interview; one conducted the interview, while the others took notes and asked follow-up questions. We concluded our interview by asking the interviewee for permission to reach out to them if we had more questions and gauged their interest in our project so we could ask them to review our mockups later.

Once we sketched and storyboarded our ideas in Miro, we received feedback through interviews and presented them to our sponsor and other employees at Simtable. By presenting the idea, feedback, and relevant background, we provided a detailed description of each idea combining the capabilities of AnySurface and Realtime Earth. Based on feedback from these meetings, we pursued multiple ideas and produced mock-ups for them. Our team incorporated any idea-specific feedback from our sponsors when we produced the mockups.

2.3 Objective 3: Build and evaluate mockups of the most promising applications

Based on the decisions we made in consultation with our sponsor in Objective 2, we employed several design tools to produce one or more mockups. Each tool is specific to the desired capabilities of the mockup. The tool recommended by Simtable is Miro, an online collaboration software for group work. Miro provided an open space workspace for ideas, so individual team members were able to both input their thoughts and view the work of other team members. We also shared the same Miro workspace with our IQP liaison, Leila Al-Hemali, which enabled us to maintain close communication. Our liaison was able to survey our ideas and process, and she provided direct advice and opinions regarding our interpretation of the project objective. This software served well in ensuring that our direction of the project is in accordance with the expectations our sponsor holds. Additional helpful software was OpenShot Video Editor, a video editing tool, Zoom, as well as Google Slides, which allowed us to illustrate our vision of operation and application of both AnySurface and Realtime Earth.

Once we produced a mockup of our idea using the tools mentioned above, we completed multiple rounds of feedback with Stephen Guerin and Leila Al-Hemali. After soliciting feedback from our sponsor on the first mockup we produced a second mockup based on the feedback we received. The main goal of the project at this point was to educate Simtable employees on the possibilities of Realtime Earth and AnySurface, as defined by Stephen Guerin. All group members were present when conducting self-paced demonstrations of our mockups to our sponsor; one group member presented and asked questions while another took notes to record any suggestions our interviewees had during our presentation. Each mockup was different; thus, the questions were different. The structure was similar for each demonstration; each major section concluded with a brief set of questions about the section's strengths and weaknesses. We finished this final set of interviews by asking three main feasibility questions:

We presented the mockups, summarized the feedback we received, and recommended future directions that Simtable might choose to pursue if they decide to prototype any of the mockups. Our group indicated the best directions for the mockups. Apart from the mockup, we also determined and shared with our sponsor the features desired by individuals currently utilizing Simtable technologies.

2.4 Conclusion

To conclude, our team created mockup(s) that utilized both the features of AnySurface and Realtime Earth in an effective and useful manner. We learned about AnySurface and Realtime Earth software while in Santa Fe, which further built upon our background research. We produced mockups combining the features of AnySurface and Realtime Earth and solicited feedback from experts on them. We presented our mockups to demonstrate possible applications of AnySurface and Realtime Earth.

Chapter 3: Findings

In this chapter, we describe the operation of the three software we worked with: AnyHazard (as part of the Simtable), AnySurface, and Realtime Earth. We conducted interviews with Simtable employees to thoroughly understand how this software operates. We also discussed privacy considerations through the metaphor of an Acequia. We transitioned to new ideas proposed by Stephen Guerin, as well as through our interviews with wildland fire professionals and experts brought in by Stephen Guerin. We presented our ideas in the form of sketches as well as our video mockups.

3.1 Software Operation

This section will detail the operation of the three-software relevant to our project: and AnyHazard (the simulation software for a Simtable), AnySurface, and Realtime Earth. This section also details the concept of an *Acequia,* or decentralized data management tool which is integral to the sketches and mockups. Each section begins with a description of the software and a flowchart. This is followed by supplemental information gleaned from our interviews, and screenshots of the operation. This completes the first objective for our project: to assess the origins, development, current state, and capabilities of AnySurface and Realtime Earth.

Several employees of Simtable provided information on the functionality, purpose, and possible future uses of the Simtable software. This information fueled the development of our sketches and mockups. These individuals include Kasra “Kaz” Manavi, the Head of Research and Community Outreach, Joshua “Josh” Thorp, the Chief of Technology Officer, and Cody Smith, a software engineer at Simtable.

3.1.1 AnyHazard - Simtable

AnyHazard is the simulation engine for the Simtable. AnyHazard uses geographic data from sources such as ArcGIS by ESRI and street map data from OpenStreetMap to produce a model of the real world. The software can simulate fires, flooding, watersheds, and smoke/chemical plumes (Stephen Guerin, Simtable CEO, personal communication, October 25, 2023). Figure 17 visualizes the operation of the Simtable with AnyHazard software.

The operation of the Simtable breaks into three distinguishable sections, shown in Figure 17: Models (top section in blue), Views (yellow section), and Controllers (bottom section in red) (Stephen Guerin, October 25, 2023). The Models section is the starting point for any Simtable simulation. The user starts the Simtable System, including the AnyHazard simulation environment, either with the keyboard or a remote to the projector (Stephen Guerin, October 24, 2023). Then the user can select a location either by panning around the Earth (input via the keyboard or laser pointer) or by typing in a specific location.

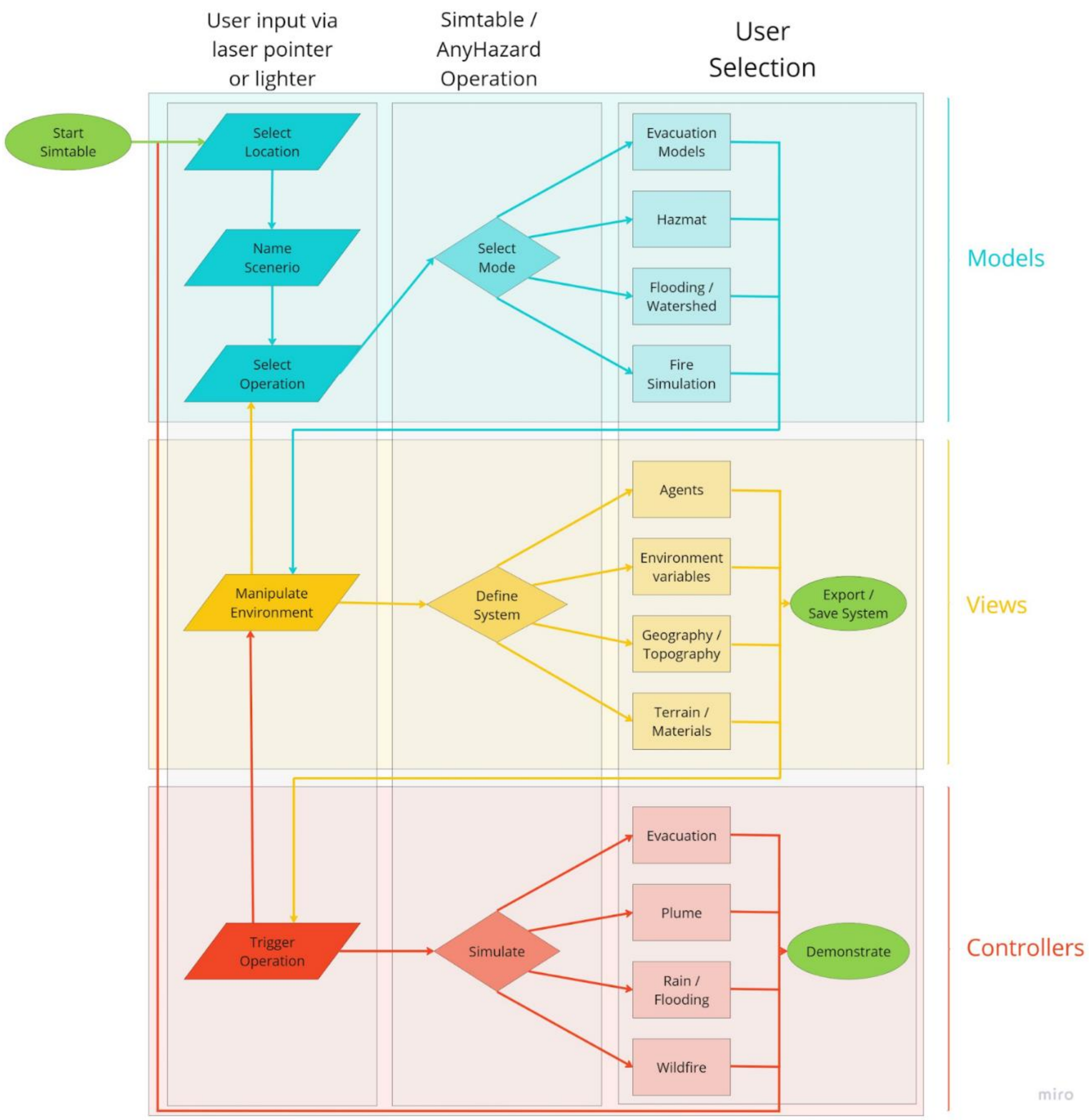
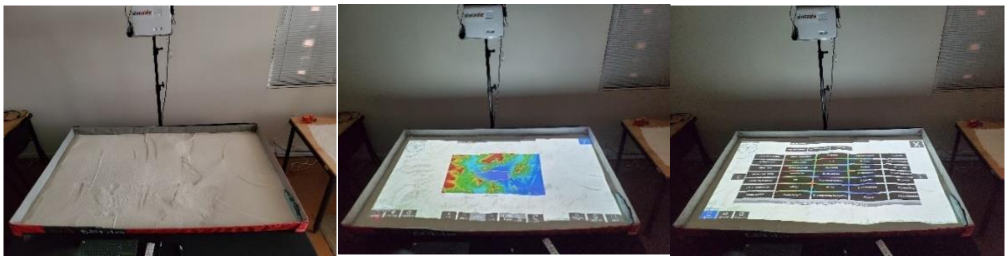
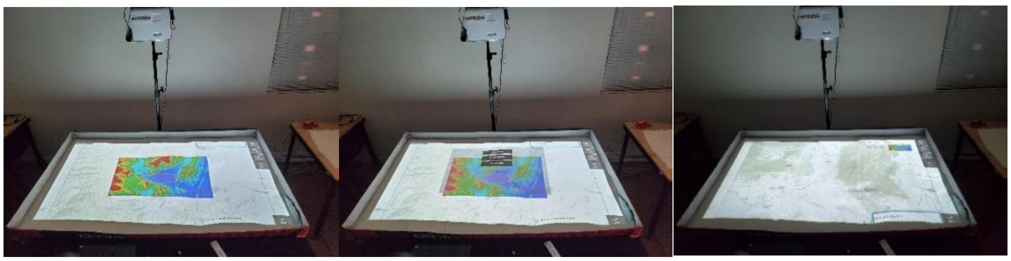


Figure 17: Simtable Operation Flowchart

Users perform operations on Simtable using three mediums: a keyboard, a laser pointer, and a lighter. The keyboard is the most precise method of user input and can perform more advanced operations like calibration of the Simtable. The laser pointer is a faster and more difficult method for controlling the Simtable. The lighter is used for lighting fires and other specific operations on the Simtable.



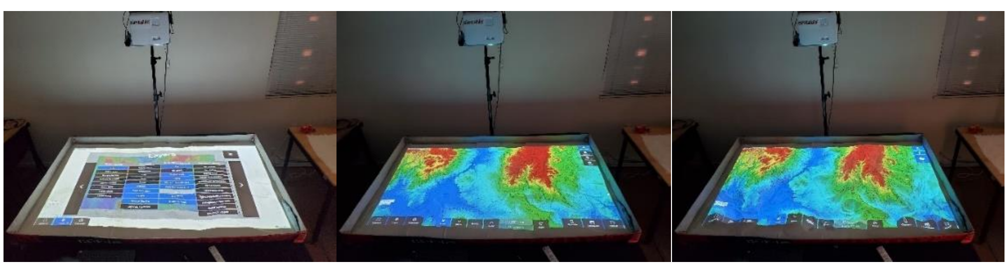
Simtable Off Simtable On – Select Scenario Select Location Menu



Location Searched Choose from Search List Name Scenario

Figure 18: Initiating Simtable Scenario

Following the images in Figure 18, once the Simtable is on, the user can select between a location-based or a custom topography scenario. With a location-based scenario, the user searches and then selects a location for simulation. The user can then name and save the scenario in case of future uses. Afterwards, the user can sculpt the sand to the correct elevations of the chosen location using the elevation shading layer shown in Figure 19.



Layer Selection Layer Shading, Pan and Zoom Sand Molded to Scenario

Figure 19: Scenario Configuration

With the scenario named, the user can then select the mode of operation. The four modes of operation available with AnyHazard are (1) Evacuation, (2) Plume / Hazmat, (3) Flooding / Watershed, and (4) Fire (Stephen Guerin, October 24, 2023). Depending on the desired operation, the user can come back to the model stage to simulate multiple models at once.

The View section allows the user to define the environment for simulation. Different agents are programmed in AnyHazard such as cars (black dots), which travel around roads provided by OpenStreetMap, as shown in Figure 20 (Stephen Guerin, October 24, 2023).

Figure 20: Car Agents on OpenStreetMap on the left & Close up of Car Agents on the right

The user can change variables within the environment such as wind using on-screen controls. At any point during the simulation, these variables can be adjusted. Inside the simulation frame, defined in the model section, the user can 'paint' various materials involved in one or more simulations. For instance, as in Figure 21, the user could paint 'Heavy Slash' (Purple) on their frame, and fire simulation would burn that area like 'Heavy Slash' in those areas (Stephen Guerin, October 24, 2023).

Figure 21: Painting the Simtable Fuels with 'Heavy Slash' material (in purple)

The user can select the visual representation of the map; the possible views are ESRI, ESRI Imagery, Topographic, National Geographic, OpenStreetMap, Bing Hybrid, USGS Hybrid, USGS Quads (list on the left side of the leftmost frame in Figure 19). Figure 22 shows a Topographic Representation of the scenario. At this point, the scenario can be saved for later operations, or the user can continue to the simulation phase (Stephen Guerin, October 24, 2023).

Figure 22: Topographic Representation of Simtable

The Controllers section initiates the simulation. The user can place any of the simulation agents: for plume analysis, the user can place plumes of different types of gas. Figure 23 demonstrates a smoke plume analysis with AnyHazard. The wind, pointed South West, drives the smoke plumes down and to the left, across the simulation environment (Stephen Guerin, October 24, 2023).

Figure 23: Smoke Plume Simulation with AnyHazard

For Evacuation, the user can define the evacuation zone using the clipboard feature or with the Simtable. Figure 24 shows the QR code projected onto the scenario so a user can use their cell phone to make changes to the simulation. From the clipboard, a user can change the wind, draw evacuation zones, paint materials, and perform other actions (Stephen Guerin, Oct 24, 2023).

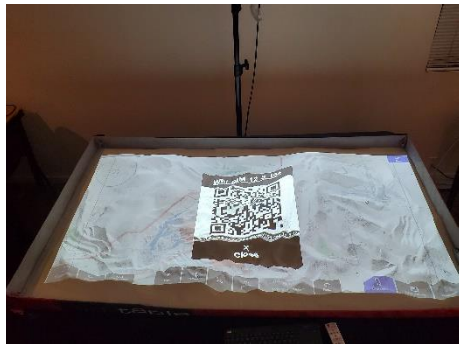


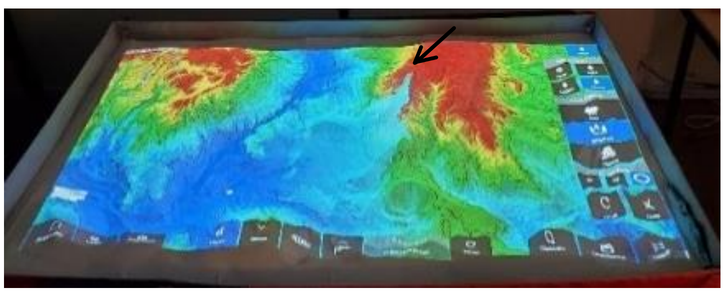
Figure 24: QR Code to Scan into Clipboard with a Cell Phone

The user can define an evacuation zone, shown on the left of Figure 25. The cars (black dots on roads) leave the evacuation zone in the right frame of Figure 25, as they would in an emergency scenario.

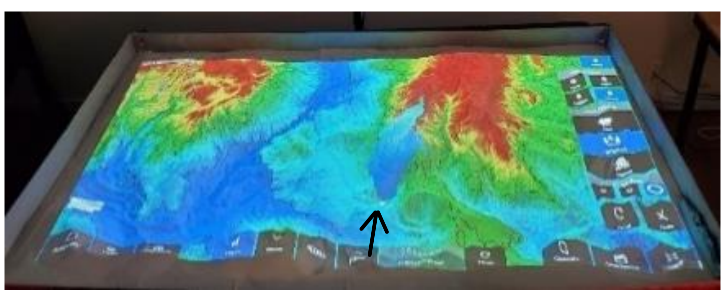
Figure 25: Left: Car Agents (black/red dots) inside an evacuation zone (in red). Right: Car Agents have evacuated the evacuation zone

For Rain / Flooding, the user places rain in various amounts and intensities, dam breaks, or watersheds. Using the laser pointer, the user can paint rain in either light, medium, or heavy downfalls, as in the upper images of Figure 26. The runoff of the rain will follow the topography of the scenario (Stephen Guerin, October 24, 2023). A dam break simulation demonstrates the effects of a dam break from a certain spot. Similarly, the watershed simulation will visualize the runoff water to a given location (Stephen Guerin, October 24, 2023).

Rain Simulations



Dam Break



Watershed Simulation

Figure 26: Water Simulations

For fire simulation, the user ignites a lighter near the surface of the sand and the camera receives the input and ‘lights’ a simulated fire there. The rate of time in the simulation can be sped up or slowed down according to the user's desire. The user can also pan around the map as well as zoom in and out to examine the simulation. The fuels for a wildfire simulation, such as dry brush, dense forest, and barren land, are accurate to 30m within the United States. The wildfire simulation burns according to those fuels. Figure 27 shows the progression of a wildfire simulation. In the first frame, the user ignites the fire. In the second frame, the user has pointed the wind South, and the fire progresses quickly Southward. The third frame shows the fire progressing even farther South. The final frame in Figure 27 shows the reaction of the fire to a wind shift Northward.

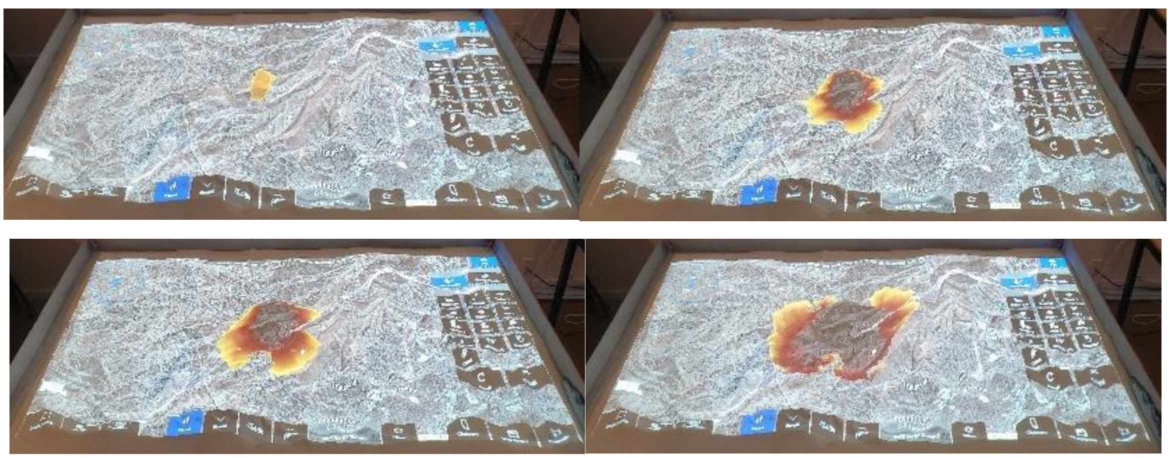


Figure 27: Fire Progress, Wind Influence

Figure 28 shows the agents the user can place in the scenario. In figure 28, the agents move and interact with the fire in predetermined ways. The agents move on specific paths as the simulation runs. Most agents are geared towards fire simulation such as bulldozer lines, helicopter/plane water drops, and fire crews. Bulldozers and crews destroy vegetation in a defined line which prevents the fire from spreading across the line. Helicopters and Airplanes drop water on live fires and put them out. At any point, the user can end the simulation and select a new location to begin a new scenario.

Figure 28: Agent Operation during Wildfire Simulation

3.1.2 AnySurface

The AnySurface software leverages a camera-projector pair to establish an interactive surface. The camera-projector pair allows for depth perception and object recognition. Simtable exercises these features in their current apps: Electric Field Hockey and Ants. Figure 29 details the operational flow of AnySurface. AnySurface begins with the user determining a surface or surfaces to project onto. We define a surface as a continuous physical plane. Once AnySurface has one or more surfaces to project onto, the user selects a space to display. A space is the projection onto one or more adjacent surfaces. With a space selected, the user projects onto the desired surface(s). The collection of spaces a user projects onto is the AnySurface layout. The spaces can now be altered or stopped at any point.

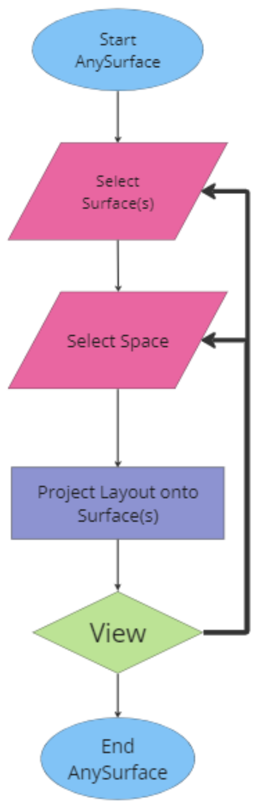


Figure 29: Operational Flow of AnySurface

AnySurface operation can range from a simple projection onto a flat wall, to a more complex ‘AnySurface Smart Warp’ as in Figure 30. Smart Warp projects a rectangular image onto an uneven surface which allows a user to view the image without distortion from a particular angle. As seen in figure 30, breaks in the projection define the edges of the surfaces. In this case, the adjacent surfaces 1-7 form the *space* which displays a movie. Because the only projection is the Smart Warp of the movie, the layout is just the space: outlined in the same red border and font.

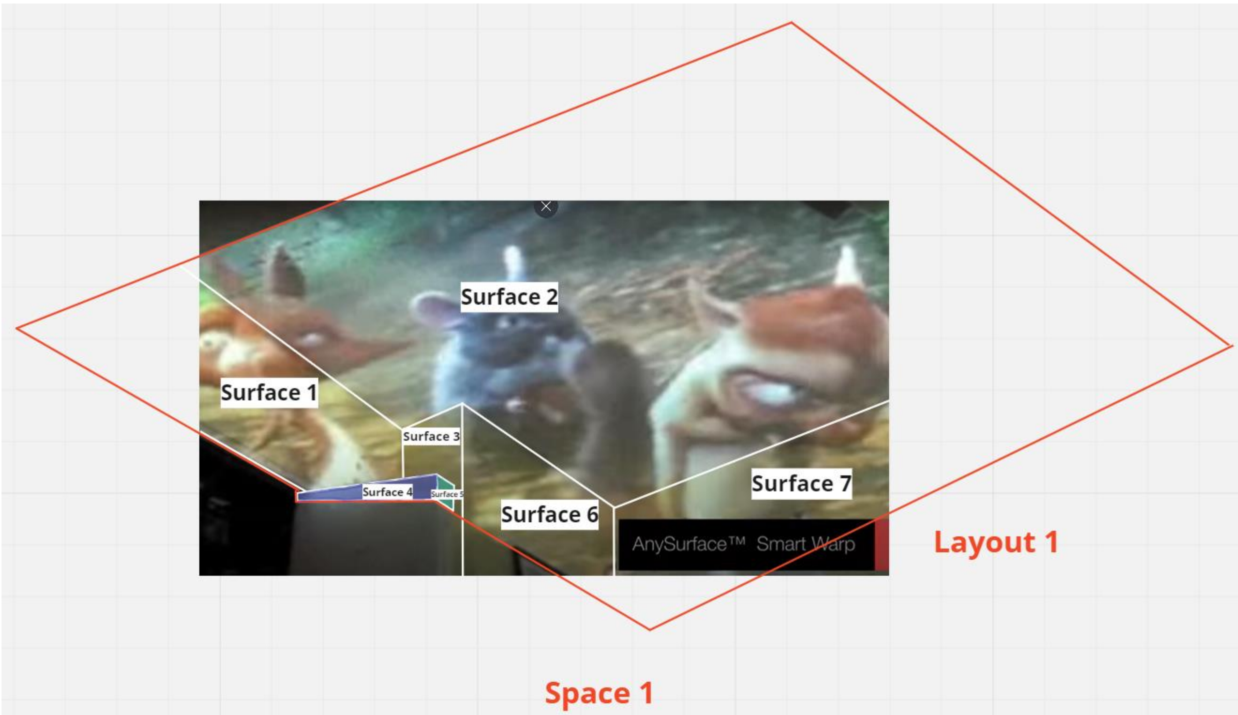


Figure 30: AnySurface Smart Warp

In the figure, one surface is the ceiling of the room, but each wall is another surface, and any interruptions of those walls, like the door frame, will also be a new surface. With this base functionality in mind, we interviewed Simtable employees to see their vision of what AnySurface is and its potential. Joshua and Kasra described AnySurface as a technology that maps a surface to a projector or camera, so it becomes interactive. Kasra said, AnySurface allows a user to manipulate space with projection (Kasra Manavi, Head of Research and Community Outreach, personal communication, November 2, 2023). Joshua concurred claiming AnySurface will transform information from traditional, restrictive computer interfaces to an interactive room (Joshua Thorp, Simtable CTO, personal communication, November 8, 2023). Kasra thought of AnySurface as an operating system, a description Joshua agreed with.

This is a key insight because when computers were first released, they ran with a command line; then Windows Operating Systems allowed for control with a mouse; AnySurface, being an interactive operating system, would require a new mechanism or mechanisms for control and display (Joshua Thorp, November 8, 2023). In order to accommodate new input forms with AnySurface, new programs have to be developed to replace existing programs, such as Microsoft Word, which was designed to work in a Windows environment with keyboard and mouse inputs (Joshua Thorp, November 8, 2023). The AnySurface OS could be controlled by user hand motion, like pointing at an app to open it (Kasra Manavi, November 2, 2023).

According to Kasra, Simtable currently uses two AnySurface apps: ‘Electric Field Hockey’ and ‘Ants,’ which demonstrate AnySurface capabilities such as object tracking. These apps serve as a case study for the operation of AnySurface (Kasra Manavi, November 2, 2023). ‘Electric Field Hockey’ is a game in which one or more users place positive and negative charges on a field to move a positive charge around obstacles and through a goal. Ants is a simulation that demonstrates how ants foraging for food will find the shortest path to a food source around barriers (Whenever we ran ‘Ants’). For both apps, the user places predefined objects on the surface to act as the charges for ‘Electric Field Hockey,’ or the barriers, food sources, and nests in ‘Ants.’ While ‘Electric Field Hockey’ and ‘Ants’ can have multiple users, AnySurface does not have to be multi-user (Kasra Manavi, November 2, 2023). ‘Electric Field Hockey’ and ‘Ants’ receive camera input from the space area as the projection, however, cameras in the room, not necessarily mapped to a projector, could allow users to interact with objects in space with the AnySurface OS (Joshua Thorp, November 8, 2023). The development of AI could improve the interpretation of user inputs (Joshua Thorp, November 8, 2023).

Additional potential uses discussed were AnySurface as a gaming or entertainment engine (Cody Smith, Simtable Software Engineer, personal communication, November 1, 2023). Kasra said AnySurface has major potential for Education and Outreach because turning a projector 90 degrees onto a table completely changes the perspective of the discussion (Kasra Manavi, November 2, 2023). Kasra said that intelligence is not on the table but around it, and AnySurface could enable better conversation (Kasra Manavi, November 2, 2023). Cody mentioned that AnySurface could be used for art and has been mocked up to be a room designer previously (Cody Smith, November 1, 2023).

3.1.3 Realtime Earth

Realtime Earth is Simtable’s tool for viewing, recording, and mapping the world. With enough cameras, the tool can produce a 3D representation of everything from terrain to a room in a building. The flow chart in Figure 31 defines the operational flow of Realtime Earth. Realtime Earth runs in the browser on a computer or other device with internet capabilities. Once the browser is opened, a user selects a region anywhere in the world, typically a city. Once the user joins the region, the user can select any camera streaming within that region. At the same time, they are prompted to share their camera stream with other users of Realtime Earth can view the user's perspective of the world. The user can view the live camera feed selected. If possible, the user can pan around the camera to change the view. The user also has the option to leave the camera and select new regions to join to view different cameras.

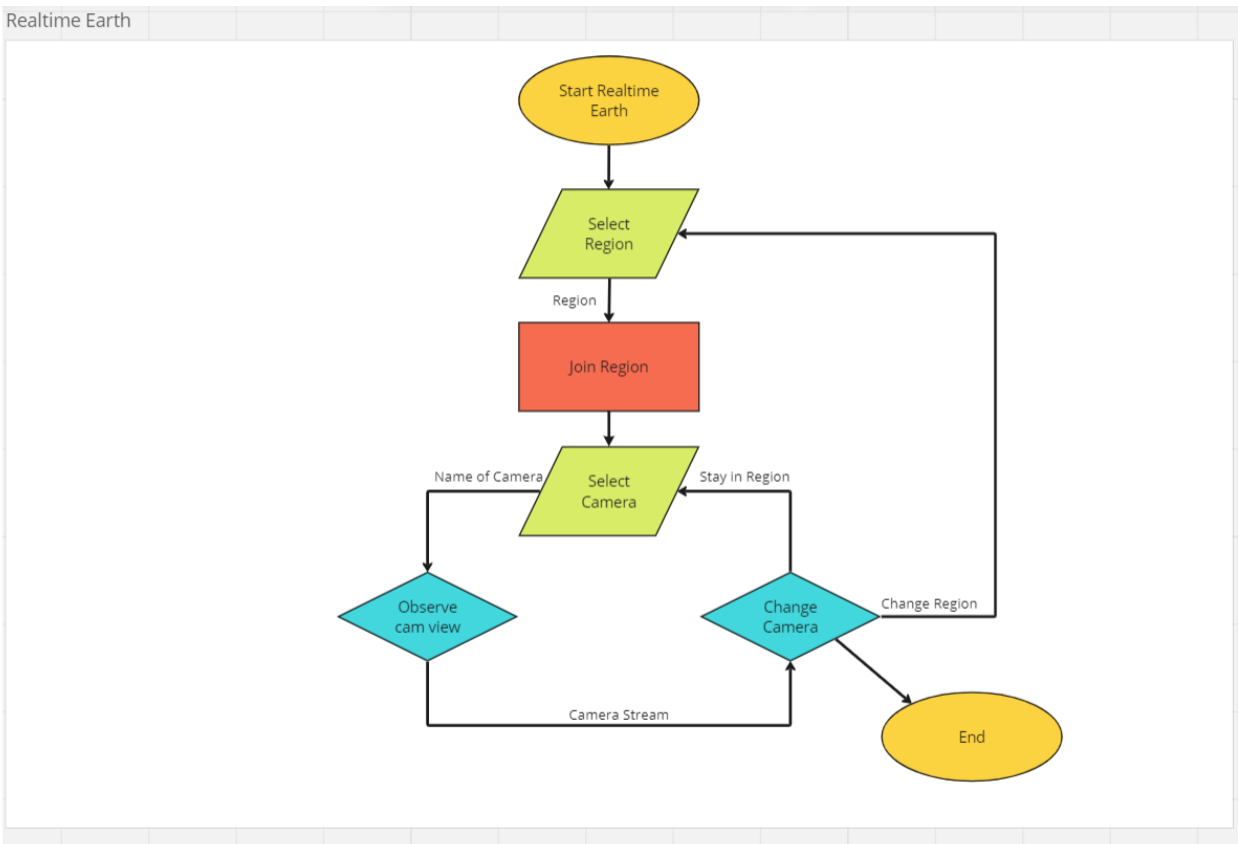


Figure 31: Realtime Earth Operational Flow

Realtime Earth could be used in the case of an ongoing emergency to give first responders and evacuating civilians up-to-date video of the disaster. A user ends Realtime Earth by closing the tab in the browser.

Our interviews with Simtable staff revealed additional details about the development and purpose of Realtime Earth. Initially, Realtime Earth was called 'Observer,' allowing a user to view other user's cameras (Kasra Manavi, November 2, 2023). Realtime Earth was built out with additional features such that now it is a “data production system” for enabling collective intelligence (Kasra Manavi, November 2, 2023). Realtime Earth became a ‘Sousveillance System,’ or a way for the public to monitor the world as opposed to a central power like a government or corporation (Stephen Guerin, November 1, 2023). To enable the goal of collective intelligence and sousveillance, Realtime Earth uses the location and orientation of a camera to map every pixel to a latitude/longitude coordinate (Kasra Manavi, November 2, 2023). Realtime Earth synthesizes additional data sources to produce a model that simulates real life (Joshua Thorp, November 8, 2023). For example, Simtable staff made a model that tracks the buses of Santa Fe. Using the buses’ GPS data and agent-based modeling, the simulation displayed the current locations of buses (with a latency of around 10 seconds), and the expected locations thereafter based on ‘historical’ and observed data. To collect data for other fire-based simulations, such as fuel measurements, forest status, or current fire status, hikers or US Forestry Services could utilize RTE (Cody Smith, November 1, 2023). Key to the operation of Realtime Earth is the use of a specific camera: an indoor camera requires a different configuration than an outdoor camera (Kasra Manavi, November 2, 2023). This means that a camera used indoors, that has a view out a window cannot be used to observe a fire at the same time as recording the indoor space (Kasra Manavi, November 2, 2023). This duality needs to be reconciled in any sketch or mockup we produce.

Joshua also raised the issues of privacy and security related to the implementation of Realtime Earth, since Realtime Earth is based on constant video monitoring of the environment. Joshua believes that to ensure complete and sufficient privacy of the people and places being sousveilled, the data collected should be under the control of the people producing the data. By contrast, with systems like Google’s Alexa, the user has little control over how the data collected is disseminated and used by third parties (Joshua Thorp, November 8, 2023).

Through collaboration of Realtime Earth and AnySurface, play-by-play in sports can provide more information and analysis to users, which can also improve the current VAR technology, visually assisted refereeing. In close and intense games, any information can be crucial and pivotal in determining the winner of the game, which only further contributes to the excitement and clarity that users demand.

3.1.4 Protecting Privacy

Simtable's technologies promote collective intelligence, or the sharing of information to improve public awareness. The main concern with implementing these technologies is information privacy and security, especially for Realtime Earth, where there is a constant flow of camera data. Without appropriate management and regulations of privacy and data collection in place, users can leak sensitive information. Simtable employees are looking into different approaches to create an information protection system suited for using Realtime Earth, AnySurface, and Simtable.

Our sponsor introduced us to the metaphor of an Acequia as an approach to data management in these software or a combination of the software. An acequia is a waterway diverted from mainstream rivers used by multiple individuals for irrigating their crops. The public resource or 'common' in an acequia is the water for irrigation; an acequia is collectively governed by people who own 'water rights' to the acequia. Elinor Ostrom proposed the eight principles of managing commons in "Managing the Commons" through observation of acequias. (Ostrom, 1990). We diagramed in figure 32 Eleanor Ostrom's principles so we could establish the Acequia system. An *acequia* has three main components, the *commons* (water - green), the *members* (farmers - red), and *management* (the rules - yellow). The *members* and *management* must actively monitor the commons.

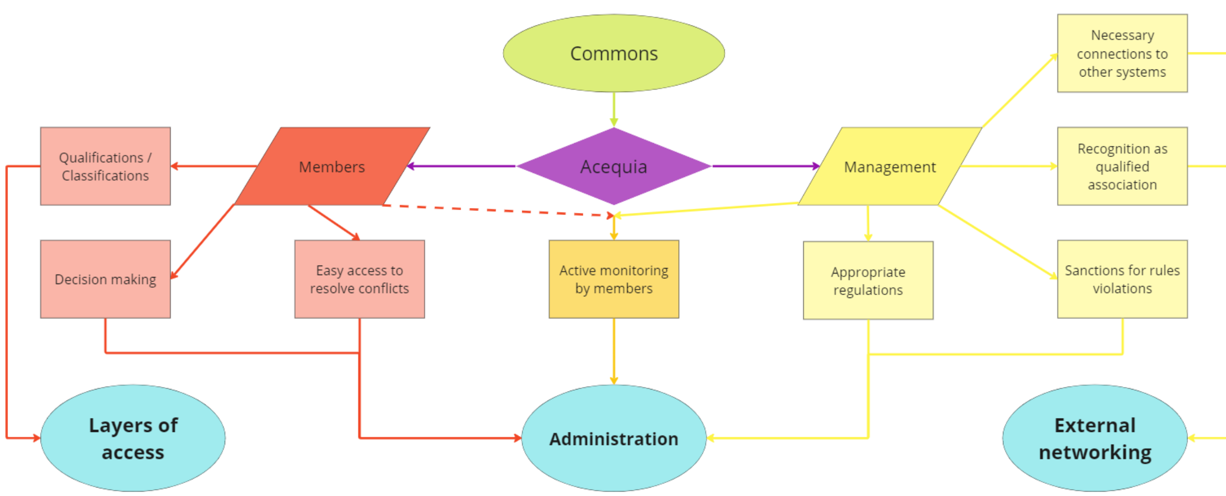


Figure 32: Diagram of Elinor Ostrom's principles within an *acequia*

Before producing our definition of an *Acequia,* we discussed *Acequias* with Simtable employees. Kasra described an *Acequia* as the flow of data from one device to another. Kasra mentioned it would be best to use the word devices in the definition of an *Acequia* instead of phones and laptops to be more inclusive to the system that implements an *Acequia* (Kasra Manavi, November 2, 2023). Kasra noted that certain peer-to-peer tools like BitTorrent and blockchain perform some of the privacy protections desired from an Acequia, but there currently does not exist a tool that encompasses all the privacy functions desired by Simtable (Kasra Manavi, November 2, 2023).

Our definition of an *Acequia* mirrors the three concepts of Eleanor Ostrom's acequia (commons, members, and management) in the context of Simtable Software: the commons are the vessel for the data, the members are the users accessing the data, and the management is the set of rules governing the data. For instance, a 'Friend Photo *Acequia'* can be a collection of photos (the commons) that a group of friends (the members) can add to, but they all must agree when they remove a picture (the management). The *Acequia* is not just the rules, but the users as equals, as well as the location of the data. It should be noted that in a system where the data is not all in one place, the location for storing data will appear as a pipeline; a Realtime Earth *Acequia* would not have a storage location, rather it would have a collection of connections (the commons) between users (members) that is governed by a set of rules (management).

Stemming from the eight principles of managing commons (Ostrom, 1990), three main fields need to be addressed in addition to our definition: Layers of Access, Administration, and External Networking, as seen in Figure 32 in blue. The first field, Layers of Access, incorporates the principle of qualifications and classification. Qualifications and classifications determine the role of a user, thus dictating the scope of information available to them. In the 'Friend Photo *Acequia,*' a qualification of the common shared data might be that a friend can remove their own photo, without any other individuals' approval. A classification of the users might be a 'Super Friend' who is known to have good taste in photos and can remove any photo at will.

The second field, Administration, incorporates decision-making and easy access to resolve conflicts under the *members*' guidelines, as well as active monitoring by members, appropriate regulations, and sanctions for rule violations under the *management's* guidelines. Administration is essential to ensuring reliable privacy protection. The ability to make decisions and convenience in conflict resolution can encourage the active participation of entrants, which, in turn, will facilitate active monitoring of the shared information by entrants. On the other hand, appropriate regulations and sanctions will discourage improper handling of information available within the community, protecting each user's privacy and information. In the 'Friend Photos *Acequia,*' administration could be performed democratically. A majority vote could be required to add a member to the *Acequia*, but a 2/3rds majority could be required for removal. User classification such as posting permission could be dictated by voting.

The third field, external networking, is essential for transiting data between *Acequias*. An *Acequia* has a limited scope of information available to it in its commons, so external connections may be necessary for some situations. The members of 'Friend Photo *Acequia,*' may wish to connect with a different group they went on an adventure with. Both groups could vote to share data; this establishes a qualified association. Then the groups propose and vote on which images to share with the other group; this fulfills the connections to other systems.

Use cases for an *Acequia* include large-scale spatial phenomena, such as wildfires, flooding, or other emergency management. For example, if there was a wildfire, citizens (members) within a community will all receive dangers of wildfire (the commons). Through external networking, people in neighboring communities will receive notice that there is a confirmed wildfire in the neighboring town(s) (shared commons), thus providing them more time to make evacuation procedures if necessary. Through approval by *members* of an *Acequia,* firefighting and emergency management agencies could have access to all information available in an *Acequia* for a limited time, allowing agencies to have an extensive range of information to most efficiently determine resource and manpower allocation to combat the wildfire.

3.2 New Uses

After completing the first objective for our project, we moved on to evaluate possible applications for Realtime Earth and AnySurface software combinations. While AnyHazard as part of Simtable is a well-established tool for fire training and response, Realtime Earth and AnySurface have not been commercially released. Thus, we had the ability to explore a wide range of possible use cases for the software. This entailed a brainstorming phase with Stephen Guerin, followed by brainstorming ideas among our group. The team produced sketches in Miro based on brainstormed ideas and solicited feedback on them from relevant experts as well as Simtable employees. Each sketch had immediate feedback presented.

3.2.1 Sketching Education Uses

Working with Stephen Guerin we determined some of the goals for our combination of Realtime Earth and AnySurface. We also ideated and came up with some viable paths for sketches. One of the first areas we explored was education. We brainstormed with Stephen and devised a set of questions we wanted to answer or explore with our sketch.

1. How can AnySurface be integrated into a lesson plan including current events and maps? (Stephen Guerin, October 25, 2023)
2. How is data shared? Who generates the data? (Stephen Guerin, October 25, 2023).
3. How is something written and contributed to an acequia? (Stephen Guerin, November 1, 2023).
4. How could students take pictures of the world? (Stephen Guerin, November 1, 2023).

Our initial thinking was that this system would require different layers, all on a base layer map, or document. Each layer contains distinct location-based data which interacts with the base layer. We proposed the class could have an *Acequia* for notes and homework to collectivize intelligence. The *Acequia* could separate questions from the homework with a Large Language Model like Chat-GPT before class (Stephen Guerin, October 25, 2023). With these ideas in mind, we produced Figure 33. A student in the class (first pane on the left), turns in their homework with Realtime Education, a software that unifies the workflow between homework and classwork. Meanwhile, the teacher reviews homework from the day prior and uses LLMs to collect all the questions from the Cornell notes (second pane from the left). In the third frame, the teacher has three screens projected (indicated by turquoise lines): one with in-class questions, one with homework questions, and one with slides of new material. In the final frame, students with an AnySurface-enabled desk can post questions to the in-class questions board and search in a browser.

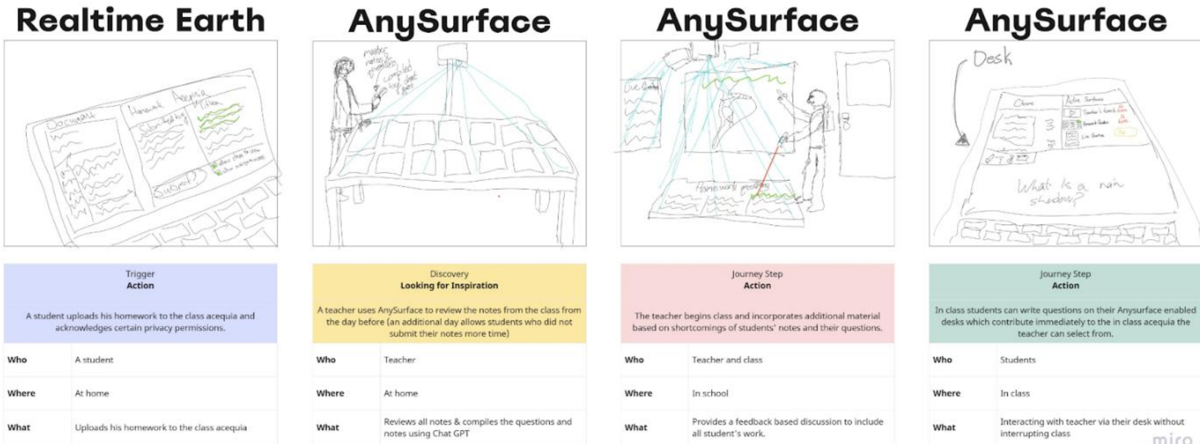


Figure 33: Realtime Education

Leila Al-Hemali, suggested including an AI filter to screen students' comments and questions on the homework before sending them to the *Acequia* to ensure they are relevant and appropriate.

3.2.2 Sketching Collaboration Uses

Guerin also wanted us to investigate the flow of information in a collaboration setting. After a brainstorming session, we devised a list of questions to answer with our sketch.

1. How can multiple people contribute to a project in an interactive space? (Stephen Guerin, November 1, 2023)
2. How can hand movements be used to control the system? (Stephen Guerin, November 1, 2023)

While these are incredibly open-ended questions, Guerin provided some guidance: the system could be a first-person view if only one person was inside; the system could resemble something like the holodeck from Star Trek (Stephen Guerin, November 1, 2023). Guerin also described AnySurface as an input system on top of any browser and we could mockup a system that uses objects to control parts of the browser (Stephen Guerin, October 25, 2023). While we elected to show a multi-user system without a first-person view, we attempted to make the system as immersive as possible. We produced one sketch, Figure 34, that demonstrates the functionality of the system while the second sketch, Figure 35, demonstrates the controls. In Figure 34 (Collab Room), the team is attempting to collaborate with one another, but the team members are in multiple places around the world. They have a consistent set of goals, but they want to contribute to one another's work. Some members of the team work in the main office in a room with multiple screens, while others work in home offices with only one or two screens. We sought to show how lab data could be contributed to the *Acequia* for the team and how someone could enter the *Acequia*.

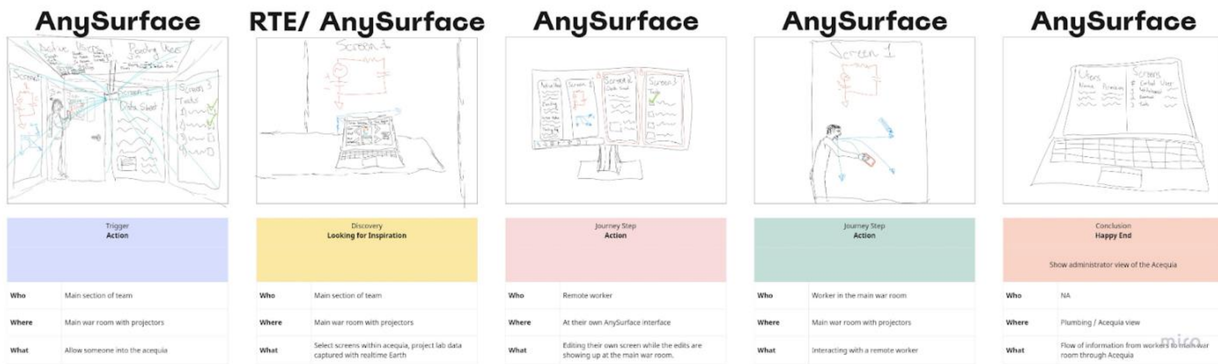


Figure 34: The Collab Room

In the first frame on the left of Figure 34, a user scans a QR code to join the team's *Acequia* and gain access to the various spaces (projections) in the room. The spaces projected in the room are notes (left), a datasheet (middle), group tasks (right), and a control panel (top). Using a personal-device-based control system, a user could make requests to access or change screens which would be shown on the control panel on the ceiling. In the next frame, a user makes a request to change the notes screen to lab data collected with Realtime Earth. The third frame shows the *Acequia* view of a remote user. Certain spaces are outlined in red with a lock symbol to show that the user cannot access them. A subtle detail is that the remote user is currently drawing in blue on the notes screen. The fourth screen shows a user in the room erasing the blue, digital lines drawn by the remote user using a physical eraser tracked by a camera positioned next to the projector. The final screen shows a manager view of the *Acequia* which would allow a manager to approve screen change requests, *Acequia* join requests, and manage the screens in the room. We were encouraged through the feedback session on this sketch to demonstrate how someone would enter an *Acequia* group.

The next sketch details our proposed set of controls for the system. The sketch features a citizen at home, overseeing different areas of the room from the same position. Both hand movements and voice inputs are registered, so certain actions translate to commands that cause changes on the display. The first frame of Figure 35 shows the spaces (1, 2, and 3) already established in the citizen's room. The second frame shows the apps displayed by the AnyApp system in the three spaces: the news (top), weather (bottom left), and YouTube (bottom right). The fourth frame shows how the user can switch tabs by pointing at the projection. Voice commands switch the information presented in the spaces, shown in the fourth frame. This functionality is helpful if the user's hands are full or dirty, like when cooking, or if the person has a disability.

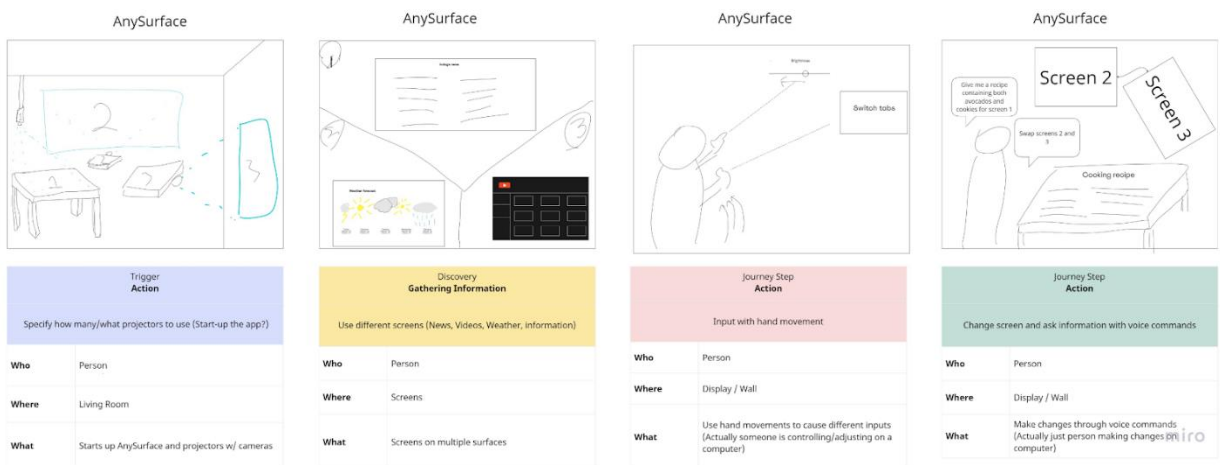


Figure 35: AnyApp

The feedback we received on this sketch from Leila Al-Hemali pushed us to think of the UI for the screens used in this scenario. Leila asked, "what would the system look like if the user wore a smartwatch to assist AnyApp with motion tracking? Could a specific hand motion get the device's 'attention' to prevent unwanted interactions?" The feedback we received on both the Collab Space and AnyApp was to investigate the permissions required to operate the system. Upon receiving feedback, we detailed the permissions and accesses required for an interactive, immersive *Acequia*, similar to the ceiling display in the collaboration space. We produced two lists of items which we desired to show with the control panel:

Data to Show	**Actions to Take**
Available Screens	Hand motions
Active Users	Voice commands
Pending Users	Select Projector
Pending Actions	Select Screen
QR code to join *Acequia*	Designate user to screen
Current Manager / Voting System of *Acequia*	Distribute access of different screens to different users
Permissions / Status of Screens	Open / Close *Acequia*
Permissions / Status of Users	Admit Members to *Acequia*
	Conflict resolution

Table 2: AnySurface Control Panel Needs

The controls for these items contain four panels: Screens Status, User Status, Commands, and Members management /administration (Figure 36). A key for the symbols in Figure 36 is shown in Figure 37. The Screens Status shows the various screens available, a short description, and the status: locked vs unlocked, viewable outside the room, and file type. Additionally, there is a section of Screens Status which shows any requests made to change a screen. The request has upvote and downvote symbols; once a certain threshold is reached, the request will go through. This demonstrates a democratic *Acequia* in which all major changes are voted on by the whole group with an interface not shown here. The User Status panel shows all current users, their screen permissions, their location, and their activity. James can access screens 1, 2, and 3. Due to 1 and 3 being locked, James is the only person who can change them without a vote. James is also in-person, as indicated by the eye. Finally, he has a green dot which shows he is active in the *Acequia*. The User State Panel has a new user section that shows a new, remote user named Kirk who wishes to join the *Acequia* and view screens 2 and 3. The Commands panel shows the actions that can be taken with the projectors and screens. The top bar of the panel (turquoise) shows the available projectors and their status (gray-disconnected, red-off, green-active). The largest section of the Commands Panel shows the relationship between screens and projectors. There is not a 1:1 ratio because multiple projects can be used for one screen (i.e. like an Imax theater) while one projector can have multiple screens (like with Windows split screen). The left section of the commands panel shows the history of the various screens. The Members' Management/Administration panel shows a vote to open the *Acequia* with a 'New Member QR code.' The panel also contains a permission request area currently showing that Bill requests access to screens 1, 2, and 3. There is also a conflict resolution panel that shows a user, their grievance, and the group's votes.

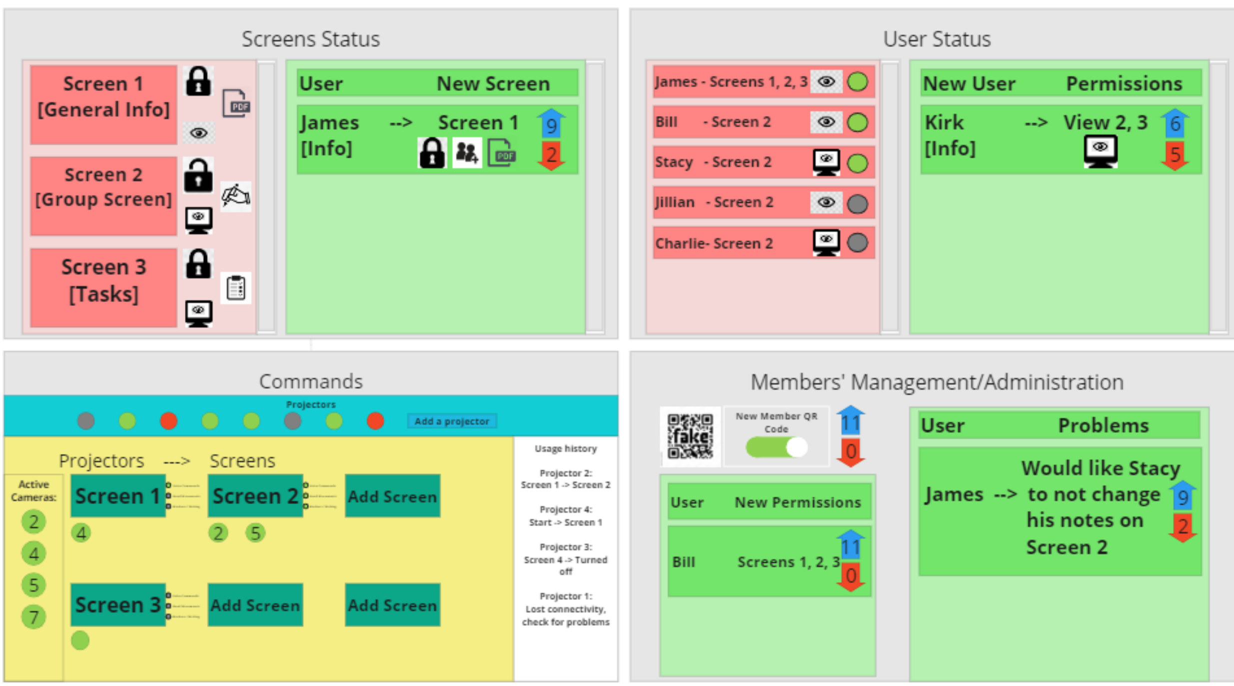


Figure 36: *Acequia* Control Panel

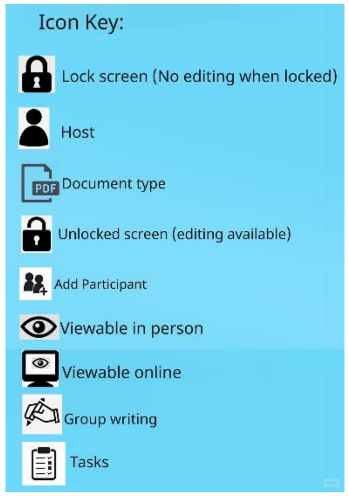


Figure 37: Symbol Key

There are instances, like in a classroom, where democracy is not the best system. We proposed a managerial system in which one person has the power to add or remove users and change screens and permissions. The manager system uses the same control panel, with a manager menu in place of the upvotes and downvotes. We detail one of the manager menus in Figure 38.

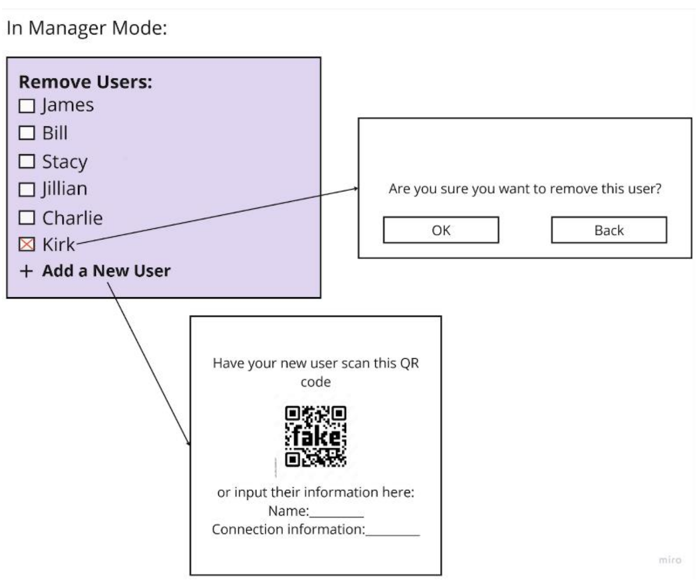


Figure 38: Manager Control System

Leila Al-Hemali has said that this sketch was the most concrete version of an *Acequia* that Simtable has. As a result, this sketch opened numerous avenues for questions. The first was a discussion pertaining to the lexicon we used. She wanted us to use a work more abstract than 'screen' to include more possible projection scenarios. We ultimately settled on 'spaces' which include both 2d projections, projections onto objects, and first-person, 3d immersive views. We were also asked to investigate the power structures in a decentralized model to bring the *Acequia* to a higher level, outside of just controls.

3.2.3 Sketching Fire-Based Uses

We were also tasked with exploring sketches integrating the capabilities of AnySurface and Realtime Earth into fire-based applications. This could entail everything from collecting data before a fire to disseminating information during a fire. We also brainstormed more fire-based ideas like using Realtime Earth with firefighters to get an active map of Simtable. Another idea was using Realtime Earth to capture regional events, like a Dia de Los Muertos festival, and posting so that individuals in their homes could use AnySurface to view the location and time of the festival so they could attend (Stephen Guerin, October 31, 2023). We discussed capturing the world with Realtime Earth to actively update a Simtable's fuels and geography (Stephen Guerin, November 1, 2023). to view the location and time of the festival so they could attend (Stephen Guerin, October 31, 2023). We discussed capturing the world with Realtime Earth to actively update a Simtable's fuels and geography (Stephen Guerin, November 1, 2023).

The first fire-based sketch we produced sought to utilize the Simtable to collectivize the intelligence of a fire response team during a fire. In the leftmost panel of Figure 39, an incident commander leading a response to a wildfire receives a report of a wind shift. In the second frame, using the Simtable, he can select the Realtime Earth feed from one of his firefighters. The third frame shows the view from the firefighter. The final frame shows how AnySurface allows the incident command to throw the feed from the firefighter onto another screen so he can always view the stream.

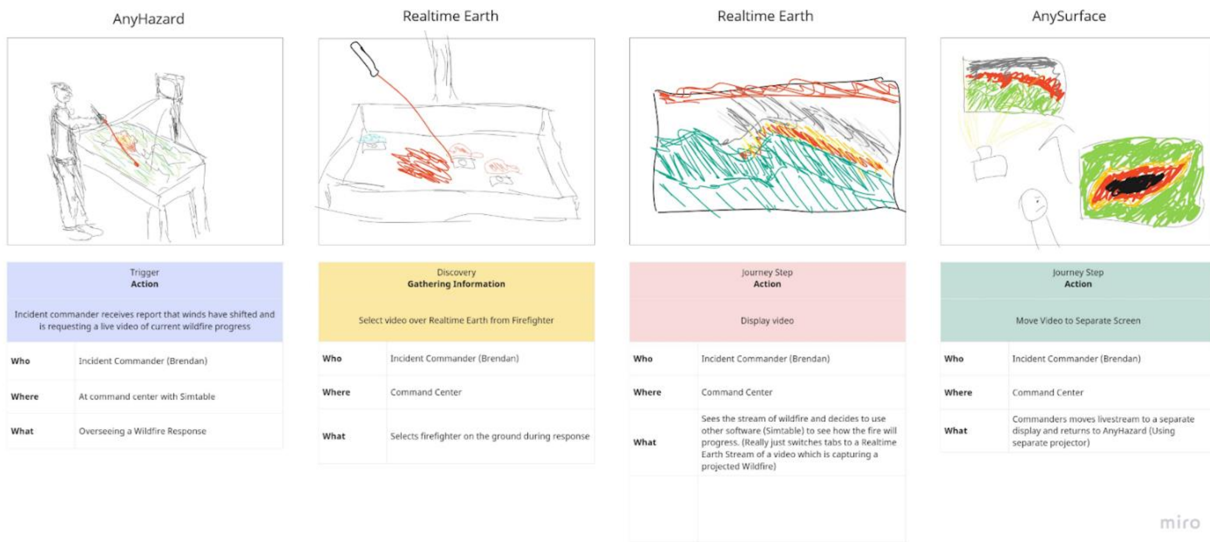


Figure 39: Realtime Fire

At the Cohesive Wildland Fire Management Strategy Workshop, we interviewed Darryl Jones, the Forest Protection Chief for the South Carolina Forestry Commission (Coalition of Prescribed Fire Councils, 2022). As Forest Protection Chief he oversees wildfire suppression, wildfire prevention, emergency response, law enforcement, training & safety. He also administers South Carolina's Certified Prescribed Fire Management, Smoke Management, and prescribed burn programs (Coalition of Prescribed Fire Councils, 2022).

When Mr. Jones first learned of Simtable and received a demonstration, he bought two on the spot and considers himself a progressive in the wildland fire prevention and suppression domain. He described an ideal future of wildland fire response with an easy flow of information between forestry workers, dispatchers, and fire chiefs like him (Darryl Jones, personal conversation, November 7, 2023). This validates the functionality we presented in the Realtime Fire Sketch. Jones noted that an intuitive system like Realtime Earth that runs on a smartphone would be beneficial to him and his workers to collect and transmit information during fire response. He emphasized that when inexperienced firefighters and forestry workers see a fire, they may not fully understand what they are looking at. As a result, they make incorrect decisions, leading to inappropriate allocations of machinery, personnel, and resources. Improving the flow of information to him and his dispatchers to triage the fire would be hugely beneficial. Currently, he receives data when a fire is seen initially and when there are changes to the fire's behavior. He receives the type of fuel the fire is burning in, roughly how many first line responders are countering the fire, and what fire departments are present. He knows the locations of all dozers, which was a recent development. His workers use Quick Capture to assess the perimeter of the fire. All other data is transmitted over the radio to dispatchers (Darryl Jones, November 7, 2023). With future fire-based sketches, we focused on permissions and the flow of data to improve communication between information gatherers such as civilians or firefighters with decision makers like emergency managers or even evacuating civilians.

This feedback pushed us to expand the functionality of Realtime Fire to include civilians as well. In addition to using the Simtable as the "nervous system" for a fire response scenario, our next sketch, Realtime Response, disseminates information to civilians and establishes both data collection and evacuation routes. In Figure 40, a city emergency manager oversees a wildfire response in a WUI (wild urban land interface). The manager is analyzing intelligence gathered through Realtime Earth to build a better response to the fire. In the first frame, the emergency manager surveys images of the WUI area under threat collected prior to the fire. He was granted permission from civilians to view the images because of the fire threat. The second frame shows a request for data from civilians to give their data to emergency managers to form a heatmap of population data. The third frame shows collective intelligence in action: the emergency manager knows how many people were affected by a newly drawn evacuation zone. The fourth frame shows a cell phone view of the evacuation route provided by the emergency manager to the civilian. The final frame shows the citizens successfully reaching the rendezvous point and the individual's data is destroyed.

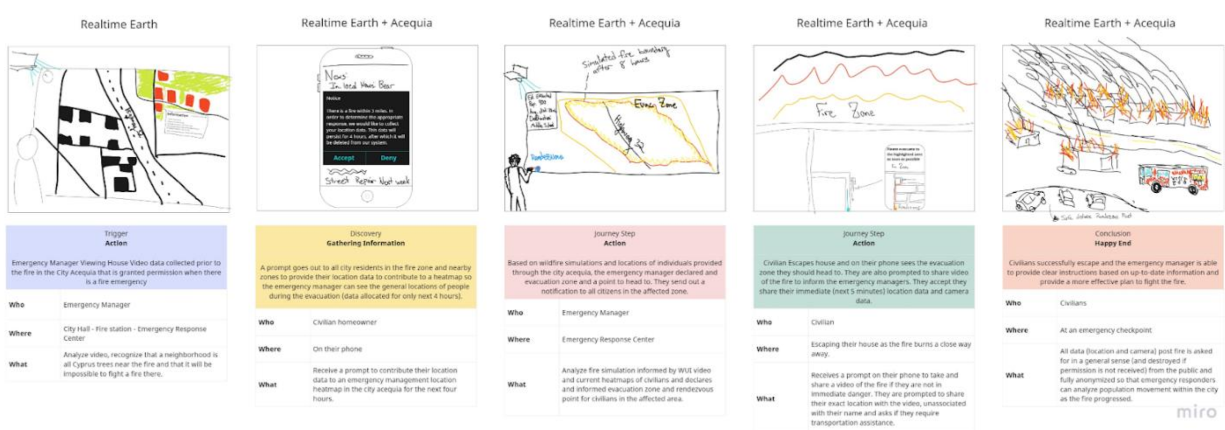


Figure 40: Realtime Response

We discussed the concepts of Realtime Response with Anthony Schultz, the ESRI representative at the Cohesive Wildland Fire Management Strategy Workshop. Schultz (Anthony Schultz, ESRI Director of Wildland Fire Solutions, personal communication, November 7, 2023) suggested creating a mockup of a map that is updated to give information about the location of a fire. While this is an intriguing avenue, the prior IQP produced an App mockup called FireTracker that performs this function (Levin et al. 2021). He also provided the team with potential directions for our project in aiding wildfire prevention. He claimed there was incredible potential if civilians could assess their home's fire risk. Information about neighborhoods before a fire could be used to create safer evacuation routes and allow emergency managers to make more informed decisions.

We proposed a system for disseminating information prior to a fire, shown in Figure 41. In the sketch, the user collects video data and contributes it to their home's *Acequia*. From the home's *Acequia*, the data can be shared with the user's insurance company to receive a quote, ChatGPT for recommendations in fire prevention measures, and the emergency management department for the city in the event of an emergency. In the first frame, the user walks around his house using Realtime Earth to capture video. The next frame shows the user contributing the video to his home's *Acequia*; at this moment he gives permission to his insurance company and ChatGPT to view the video, while giving emergency planners the ability to view it with all sensitive information like windows and license plates blacked out. As mentioned by Schultz, exposing this information to emergency planners during a fire allows them to know whether a neighborhood can be saved, or whether it should be abandoned during a blaze, saving firefighters key time (Anthony Shultz, November 7, 2023). The third frame shows an insurance agent analyzing the video and providing an accurate quote. Similarly, the fourth frame shows an emergency manager viewing the video to assess the fire hardness of the neighborhood. The final frame shows the feedback the user received from ChatGPT which indicated fire hazards and what should be done.

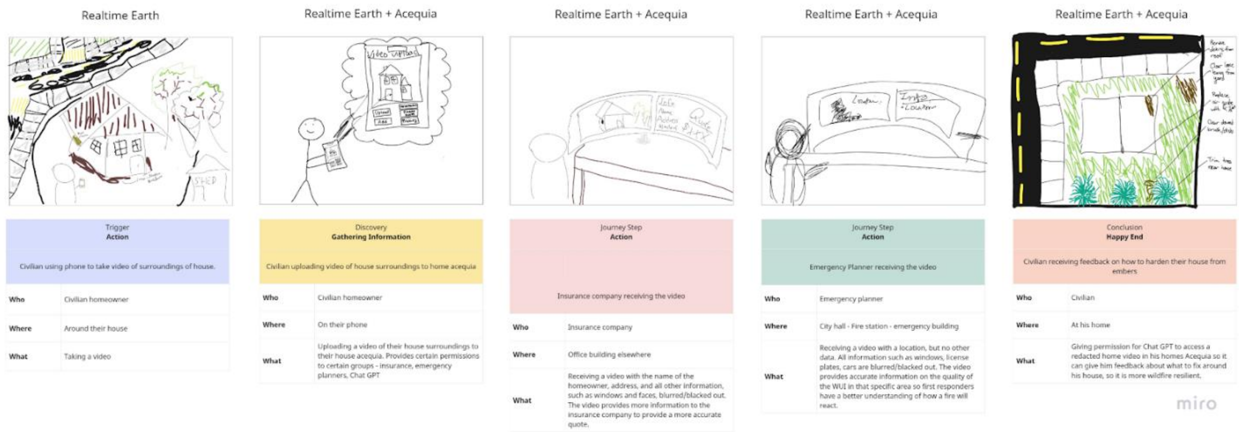


Figure 41: Realtime Survey

3.2.4 Sketching Miscellaneous Uses

While the team brainstormed about other sketches, we developed the idea for a social media system that combines AnySurface and Realtime Earth. We proposed a system, Realtime News, which captures events with Realtime Earth and presents them on different layers using AnySurface. In Figure 42, the user walks over to their coffee table in the morning and sees their Realtime News displayed. In the second frame, the user sees their surrounding area displayed on the table and various events that occurred that day. This demonstrates the 'public' layer which all Realtime News users can see. Users can RSVP to these events (frame three), so organizers and officials know roughly how many people to expect. There could be additional layers like friends and family which allow users to upload where and what they will do that day so their friends and family can join them. The fourth frame shows an official's view of the public layer so they can prepare proper road closures and personnel around the city.

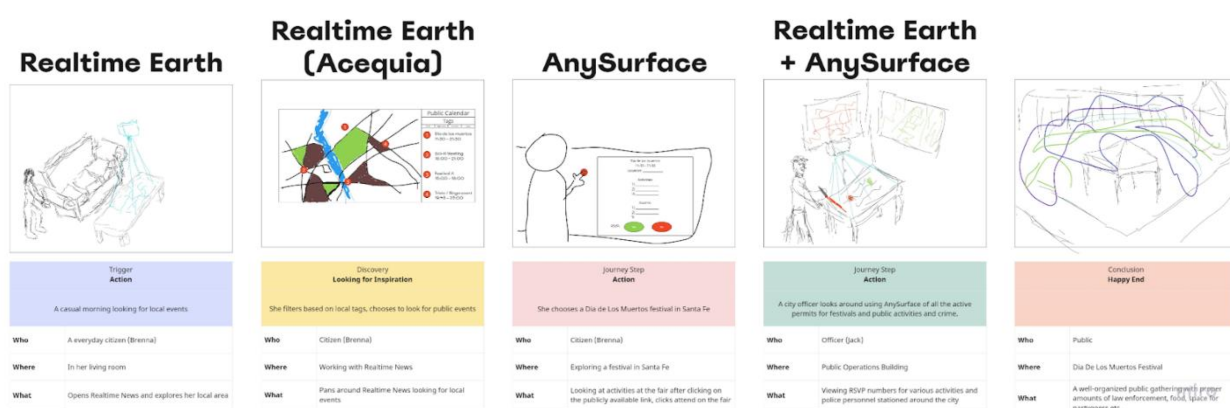


Figure 42: Realtime News

Our sponsor appreciated the inclusion of a projection on the table in a person's home. This is an idea we pursued in a later mockup. Guerin also wanted us to investigate projecting the vital signs and certain organs/structures of a patient onto them to better inform doctors (Stephen Guerin, November 1, 2023). Figure 43 visualizes our thinking: an experienced surgeon, in a remote location, observes a surgery performed by a new surgeon. The experienced surgeon has access to the hospital's *Acequia* and watches the surgery using Realtime Earth. They are on a secure network that prevents access from individuals attempting to steal information. The face of the patient and any extraneous information about the patient is blurred to maintain the patient's privacy.

Under the observation of the experienced surgeon, the performing surgeon begins the surgery. The performing surgeon pulls up the vitals of the patient and projects them onto the patient using AnySurface to allow for easier observation. The surgeon no longer needs to look up from surgery to view important information. While watching, the high-profile surgeon can provide guidance. Using a combination of Realtime Earth and AnySurface, the experienced surgeon can answer the new surgeon's questions and monitor the surgery through observation. When the new surgeon makes a potential error, the experienced surgeon can guide them through it to ensure that the mistake is not fatal.

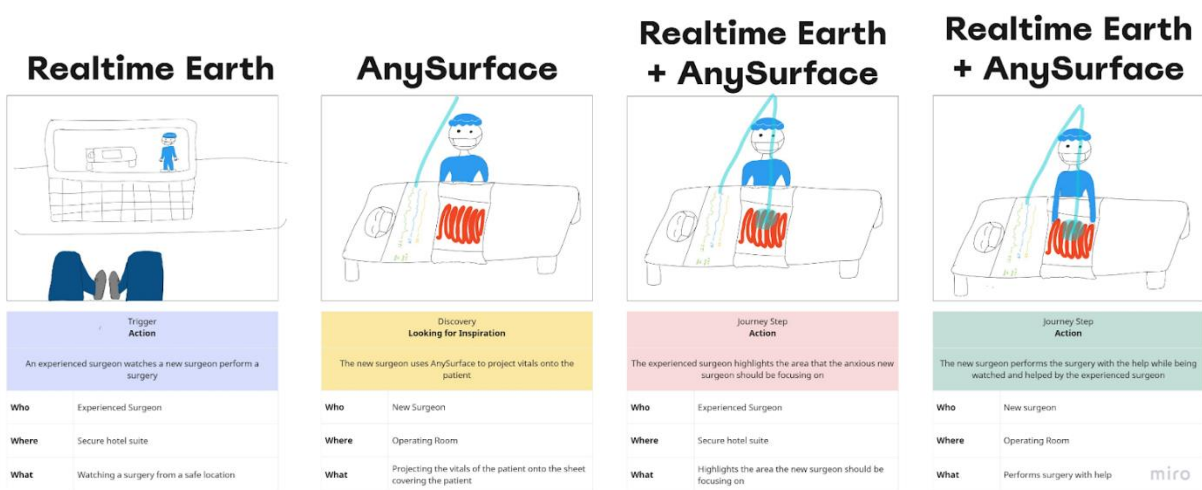


Figure 43: Realtime Medicine

Our sponsor wanted us to demonstrate how Realtime Earth and AnySurface could be used in the medical field and gave the example of a surgeon projecting vitals onto their patient.

We expanded on this idea by including the potential of another surgeon being able to observe and provide guidance for the surgery without needing to be in the room.

3.3 First Mockup

Our first mockup demonstrated an expanded version of the collab room and using object tracking to control the system. We show how a home would be immersive with 'smart light' or ubiquitous projection to light a home. We also emphasize the use of this system to communicate with elderly or immobilized individuals. A hospice patient can use this system to stream a view of grandchildren as opposed to staring at blank walls. Finally, we show how the system with camera tracking can be used to control an application.

3.3.1 Mockup Plot

The plot of the mockup features an individual in hospice who would like to see their family while unable to visit. A family member who wants to show their relative in hospice what they are up to, streams a video of themselves. The mockup starts with relative A sleeping. Relative A wakes to his AnySurface Home OS starting up - a visual alarm. He starts his Home OS app on his phone and walks over to the projection in the room. The home screen for the Home OS, Figure 44, in his room displays the weather, time and notifications. He can view his current *Acequias* and start certain spaces as well as cameras around his house.

First, Relative A starts the space which connects the kitchen camera to Relative B, his sister who is immobile. This opens the stream of data to his sister, but there is not yet any data to show. Then Relative A starts the camera in the kitchen which is linked to his sister's room. Relative B can now see Relative C playing guitar in the kitchen. The AnySurface App also allows a friend of Relative B to set up a new screen in the room with a scroll of photos. This demonstrates functionality that could greatly improve the wellbeing of a monotonous hospice life.

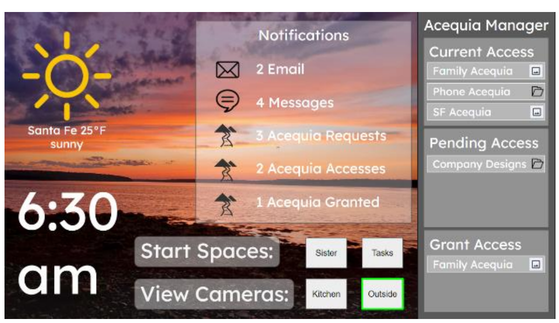


Figure 44: Home OS Home screen

Relative A, back in his room, turns off the camera facing outside. The camera outside is broken into three panels designating the sections streamed to various groups. The system streams the top section in red to Santa Fe Fire while the middle section in blue is streamed to Relative A's neighbor. The bottom section showing the user's porch is not streamed to anyone because it is private data.

Relative A walks to his kitchen and starts his corporate/job acequia. He starts his tasks screen and his notes screen using the AnySurface App on his phone. This starts the entire work *Acequia* for all members. Starting the system in his home starts the QR code at the workplace for users to scan in to. This allows User D to scan the QR code on the door when he arrives at work. User D uses the AnySurface App on his phone to turn on a projector and view the permissions on for each screen. Finally, User D uses his phone as a Realtime Earth camera to track an object on the table he uses to control a 3D design app.

The video mockup is found at this link:
https://drive.google.com/file/d/1YpZ46zEeYotsSZvbJTJLFInloVb8_JNP/view?usp=drive_link

3.4 Second Mockup

We based our second mockup on the possible applications for both AnySurface and Realtime Earth in a fire prevention and wildfire fighting setting. Simtable allows emergency management agencies to manage, plan for, and combat wildfires. Simtable employees are also delving into the field of community outreach and education, to inform communities on risks and hazards that are present around them, and actions that can be taken to mitigate these dangers.

In terms of emergency management, we believe Realtime Earth can be integrated into the system to allow the newest information for the most accurate simulation of the wildfire spread. In doing so, emergency management centers and fire personnel will be able to make the most optimal decisions where every second counts.

On the other hand, we also demonstrate how Realtime Earth can be utilized from a civilian's perspective. Through Simtable's technologies, normal civilians will be able to gain further clarity on fire risks around their homes, actions they can take to prevent that, as well as evacuation procedures in times of an emergency.

3.4.1 Second Mockup Plot

The second mockup opened to a user releasing information to their insurance agency through the Realtime Earth camera. By using AnySurface, the insurance agency is able to give an estimate based on the potential fire risk of the user's house. The insurance company also informed the first responders of the fire risk potential which allowed them to make a more informed plan for the area in the event of a fire. Within the mockup, the insurance agent accepted the invitation to the acequia and highlighted areas of concern to give the user a better understanding of what should be changed in the future.

In a new scenario, a user set up a community communication screen which they displayed on their coffee table using AnySurface. With the AnySurface application, the user was able to alter the coloration of the coffee table using Room Painter, a functionality of AnySurface that allows for remodeling and more artistic expression within a room. The user then joined the community Acequia after being accepted through several permission screens. This allowed the user to see Realtime News, which gave them a better understanding of the events of their local community, showing the day-to-day application of the software.

To showcase a community outreach and education angle, another scenario opened with a fire chief showing the neighborhood, both the crowd present and a virtual crowd, how to strengthen homes against fire by running an AnyHazard simulation of a fire in the neighborhood. Citizens drew on fuel for the fire either at home or in person using AnySurface. Realtime Earth is then used to see Dale Ball which is then closed off in the simulation due to the fire.

In the final scenario, the potential emergency applications for the software were demonstrated. A user was woken by an emergency signal flashing red and was giving a warning of a fire in the area. They were given an evacuation route and safety tips which allowed them to leave without issue. They also gave access to their location in order to allow emergency responders to know where they were. The incident commanders saw where individuals were moving and prevented them from dangerous areas. In the fire, a firefighter was given a route drawn with AnySurface onto their visor to save an immobile individual from the fire.

3.5 Third Mockup

Corresponding to our sponsor's feedback, we created another mockup that demonstrated similar ideas to mockup two. However, the mockup was shorter and showcased specific concepts that we were asked to emphasize. This mockup highlighted the use cases of AnySurface and Realtime Earth by showing a Homeowners' Association meeting with an audience of in-person and virtual people. Through this mockup, we demonstrated the wide variety of usage of Realtime Earth and AnySurface with Simtable's virtual assistant, 'Max'. The setup of the scenario was an important feature as it demonstrated the versatility of the software as several devices were used and set up to allow for group observation and alterations to the simulation.

3.5.1 Third Mockup Plot

The mockup began with a scenario of a meeting between two neighbors to discuss fire scenarios to ensure that the community understands potential fire hazards, takes corresponding preventive measures, and are familiar with evacuation measures.

The scenario included setup situations including using a mobile device to draw changes on a whiteboard which is then represented on AnyHazard. The mobile device was moved into the correct position and the greycode was displayed demonstrating that the area was interactive.

The neighbors were then able to recommend areas that they believed should be thinned to slow the spread of fire. One neighbor suggested a small area that could be thinned due to its proximity to the road that seemed to be the most at risk. Another neighbor can create a larger recommended area on their personal device based on the spread of the fire that was shown in the simulation. This alteration was then proposed to the other neighbors, and through discussion, the neighbor with the original suggestion accepted the changes.

The video mockup is found at this link:
https://drive.google.com/file/d/1_t4xbfr32j0h-oDOzMDc_wCfBBryU6Gz/view?usp=drive_link

Chapter 4: Conclusions/Recommendations

While the technologies Realtime Earth and AnySurface are still in development to improve upon the Simtable System, they have the potential for innovative and practical uses. After brainstorming, sketching ideas, and producing two mockup videos, we have developed two sets of conclusions related to each mockup. The first mockup details a Home Operating System that integrates spaces (projector-camera pairs), Realtime Earth camera feeds, one-directional information streams, and phone controls into the user’s daily life at home and at work. We conclude that:

(1) AnySurface could be designed as an interactive home/room operating system.

(2) Controls to AnySurface may be touch-sensitive or via a phone.

(3) *Acequia(s)* control data flow in a user’s system and between users.

(4) Entering an *Acequia* happens through QR code scanning plus manager/group approval.

(5) A major use case for this system is establishing a connection to an immobile individual, such as those in a hospice care setting.

We present five recommendations for how Simtable can pursue these conclusions to fully integrate AnySurface and Realtime Earth in home and work environments for collaboration and communication.

1. We recommend that Simtable expand on its current AnySurface Software solutions and produce a preliminary environment for running and controlling them in the browser. This would entail constructing menus and controls for an education-based system (building on Electric Field Hockey and Ants) that utilizes the duality of cameras and projectors. An additional interface for controlling AnySurface from a phone would be necessary for both setup and low-level control of spaces. From there, the system could be expanded to include controls via objects in a room tracked by cameras. Once this system is built with quality controls and interactive apps, it could be expanded with basic editing tools to mimic existing software such as Word and PowerPoint.
2. We recommend a system similar to AnyHazard's 'clipboard' be developed to serve as the control panel for an AnySurface System. The control panel will open a user's Acequia(s) to other users, set up and manage projector-camera spaces as well as Realtime Earth camera feeds. The control panel also allows the user to 'throw' a screen to a space and have interactions with the space. The space itself should be controlled via gestures/touch, in addition to the control panel. Essentially, a phone would supplant the current laser pointer-based interaction, and gestures would be added so a user would not need to have their phone with them constantly.
3. We recommend the entire system be constructed around the Acequia concept. All data for a specific user, shared data, and relationships between users will be stored in the Acequia. We recommend two Acequia systems: a manager system, and a democratic system. A single user, an educator, or a corporate environment would utilize a manager system with central power to one or a set of users. A group of friends sharing media or images would have a democratic system with a voting mechanism for both adding or removing members and changing permissions. The Acequia should also storeroom configuration data so a set of spaces could easily be reestablished either in person or remotely.

4. We recommend, to maintain security over an Acequia like a collaborative space within a company, a QR code controlled by a manager could be displayed to allow an individual to ‘enter’ the Acequia. A QR code could be used to unlock doors and grant access to certain files or spaces. The QR code scanning would be integrated within the AnySurface control panel on the User’s devices.
5. We recommend building this system with Asymmetric flows of data. This means that once one user gives permission, a second user can provide live streams of data, and flows of pictures or change the conditions in the first user’s room. We envision this configuration for a hospice care patient, or an immobile individual (the first user) so they can have a connection with their family (the second user). Realtime Earth cameras controlled by a family member could stream feeds of grandchildren playing to an elderly relative.

The second mockup, due to time constraints and sponsor recommendations, was never filmed. However, a script and accompanying materials were created and these demonstrated a Fire Response system integrating Realtime Earth, AnySurface, and AnyHazard. We conclude that:

1. Realtime Earth could be used for surveying/data collection prior to fire.
2. Different *Acequias* could control data flows to insurance, emergency preparation, and homeowners/neighborhoods.
3. Realtime Earth could improve communication during an emergency with location-based collective intelligence tools.
4. Realtime Earth could improve simulation accuracy during an emergency through live data streams of a fire.

We present five recommendations for how Simtable can pursue these conclusions to fully integrate AnySurface and Realtime Earth in a fire response environment.

1. We recommend Simtable further develop a Realtime Earth-based solution to collect camera data on users’ property to survey fire risks and maintain security. This process can include a fire risk assessment to prompt the user to mitigate fire risks around their house. further develop a Realtime Earth based solution to collect camera data on users’ property to survey fire risks and maintain security. This process can include a fire risk assessment to prompt the user to mitigate fire risks around their house.

2. We recommend that Simtable utilizes the *Acequia* concept to control fire risk data collected through Realtime Earth. Insurance agencies could provide quotes based on information gained from a client's *Acequia.* The clients could negotiate better rates by reducing fire risk to their property. Emergency protocol planners could have access to homeowners' *Acequias* to create more accurate simulations that better inform decisions during a disaster.
3. We recommend that Simtable explore the use of Realtime Earth to improve communication between first responders and civilians during fires. Users could stream location and camera data to first responders for a limited time. This information could be integrated into Simtable operation to synergize the flow of simulations and live data during a fire. Additionally, civilians in a neighborhood could share data to better prepare themselves in the event that there is an emergency. For example, preparations can be made if someone requires mobility assistance to extricate a home. use Realtime Earth to improve communication between first responders and civilians during fires. Users could stream location and camera data to first responders for a limited time. This information could be integrated into Simtable operation to synergize the flow of simulations and live data during a fire. Additionally, civilians in a neighborhood could share data to better prepare themselves if there is an emergency. For example, preparations can be made if someone requires mobility assistance to extricate a home.
4. We recommend Simtable leverage data collected via Realtime Earth to perform fire simulations in times of emergency. Through the combination of prior and current information, emergency responders could decide whether an area should be saved or evacuated during a fire.

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Appendices

Appendix 1A: Interview Preamble:

Hello ***[Name]***, As you may know, we are a group of students from Worcester Polytechnic Institute (WPI) conducting a research project in collaboration with your company Simtable **[if interviewing someone outside Simtable, we state we work with Simtable]**. Our goal is to mock up a use, or uses, for the new technologies: AnySurface and Realtime Earth. We would like to solicit information from you about the operation of the two technologies, their uses, and possible combinations **[if interviewing someone outside of Simtable, we ask just about their uses].**

As we currently understand it, AnySurface is a technology that allows multiple individuals to project onto multiple screens in a room at once, and Realtime Earth is a crowdsourcing/sousveillance tool that allows an individual to share their location and camera feed to upload real-time video of current events such as wildfires or flooding.

Thank you for agreeing to participate in an interview with us to discuss the technologies, Any Surface and Realtime Earth. To your knowledge, participation in this interview is completely voluntary, and you may discontinue the interview at your discretion at any time. We will be taking notes throughout our conversation and may wish to quote you in our final report. Would you mind if we quote you by name or would you prefer we keep your responses anonymous? *****[Note Yes/No]***** If we wish to use your quote, we will give you the opportunity to review the quotations prior to publication. We are also happy to provide you with a copy of the report once it is completed. Thank you for your assistance in our research.

Before we begin, are there any questions you may have? *****[Note any Questions]***** If you have any questions or concerns following the interview please contact us at gr-sf23.sim@wpi.edu or our faculty advisor, Dominic Golding, at golding@wpi.edu.

Appendix 2A: Example Interview Questions for Simtable Employees:

These questions demonstrate what we would ask when conducting an interview reviewing AnySurface and Realtime Earth. The intended interviewees for these questions are employees at Simtable.

*****Overarching Questions*****

AnySurface

How would you describe AnySurface?

How does AnySurface operate? (from a functionality standpoint as opposed to the technical side)

What use cases do you see for AnySurface?

Realtime Earth

How would you describe Realtime Earth?

How does Realtime Earth operate? (from a functionality standpoint as opposed to the technical side)

Where do acequias fit in the operation of Realtime Earth?

Provide an explanation of acequias from Elinor Ostrom if necessary

What use cases do you see for Realtime Earth?

Combination Software

How could these technologies be combined?

Reconvene

Would you like to brainstorm ideas with us at a later time and receive updates on our progress?

Appendix 3A: Example Interview Questions for Firefighting Related System:

These questions demonstrate what we would ask when conducting an interview with a firefighting expert who currently or previously used Simtable. The intended interviewees for these questions are firefighters, fire captains, ICS operators, and community leaders engaged in wildfire response.

1. What are the best features of Simtable?
2. What does Simtable not do well?
3. What are the most pressing problems within wildfire response?
4. Do you believe Simtable solves a major or minor problem in fire response?
5. What features would be useful in the future?
6. How might they and others use extensions to the existing software?

At this point, we will explain the current implementations of AnySurface and Realtime Earth which expand on Simtable's capabilities. We will include demonstrations of the current technology as necessary to clearly portray their capabilities to solicit informed feedback. We may ask for follow-up interviews to discuss and evaluate our mockups which employ AnySurface and Realtime Earth.