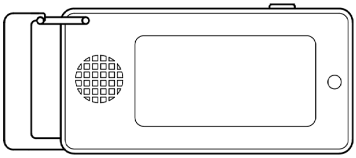
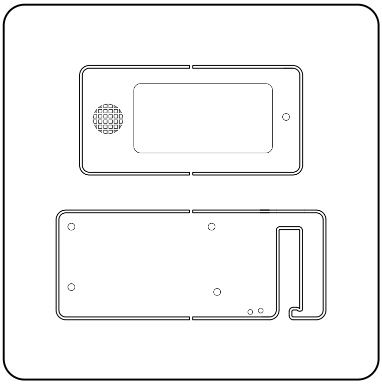
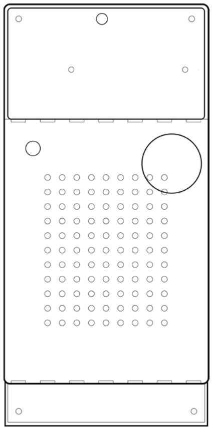
[Tech]tonic
Toolkit







[Tech]tonic Toolkit

A student-focused STEM kit that assembles into a functional messenger using adhoc mesh radio networks. The assembled device and accompanying infrastructure are designed to enable emergency communication when traditional telecommunications go offline. [Tech]tonic toolkit provides an affordable, resilient, and scalable communication lifeline to connect children, parents, and schools in the immediate aftermath of a major earthquake.

By addressing blind spots in contemporary civil infrastructure, this project illustrates how thoughtful deployments of simple technology can connect communities in the common cause of protecting vulnerable populations.

Tomas Garcia

Abstract

The US Geological Survey has identified the Hayward Fault, passing immediately underneath Berkeley's campus, a 'tectonic time bomb', declaring it one of the most dangerous in the country because of its proximity to urban centers. When these impending earthquakes arrive, the ubiquitous connectivity provided by high-speed voice and data networks enabling our individual and collective endeavors will go offline and remain unavailable for hours, days, or weeks. Despite rigorous attempts to communicate this potential reality by regional, state, and federal governmental institutions, overwhelming portions of society remain unresponsive and unprepared, ensuring an exacerbation of the emotional shock and suffering that will arrive with the physical shaking. [Tech]tonic Toolkit is a DIY-kit that assembles into a functional mesh network messenger designed to align with primary-school curriculums focusing on STEM and Earth Sciences. Distributed and maintained through public schools in seismically active regions, this project provides an opportunity to create an affordable, resilient, and scalable communication network that can be used for basic communication among our most vulnerable populations in the aftermath of a high-magnitude earthquake. By introducing and maintaining these tools through primary school curriculums and facilities, these municipal institutions have the power to provide a resilient and accessible lifeline to a wide socioeconomic spectrum, created for and powered by community. This research will not seek extensive progression of the functionality of the proposed technologies but will focus on integration and presentation of these technologies in a strategic distribution and deployment model to maximize utility and accessibility. By addressing blind spots in contemporary civil infrastructure, this project intends to illustrate how thoughtful deployments of simple technology can mitigate human suffering. While this research will focus on the Berkeley Unified School District as a pilot application, continued research into this domain might consider how these technologies can be applied to school districts of varying scales and socioeconomic circumstances.

[Tech]tonic Toolkit

Tomas Garcia

A thesis submitted in partial satisfcation
of the requirements for the degree of

Master of Design
at the
University of California, Berkeley

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Faculty Director Signature and Date

Associate Director Signature and Date

Strange and mysterious
things, aren't they–
earthquakes?

We take it for granted that the
earth beneath our feet is solid
and stationary. Suddenly one
day we see that it isn't true.

Haruki Murakami

❤

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Nic Garcia

Dedicated to the memory of
Robert Garcia

Keep Dancing

"Many inquiries were made at the telegraph office, on Seventh Street, to know if any dispatches had been received, descriptive of the effects of the earthquake there, but for some reason the telegraph communication was not complete with San Francisco…"

1868 Hayward Earthquake (10)

Image: *San Leandro Court House*, ID 48052:152, Huntington Library

History

This project exists at the intersection of earth science, telecommunications, and community disaster-response. A foundational resource in understanding this domain and this project is The HayWired Scenario, a collection of publications, visualizations, media, and resources produced over the past five years by the US Geological Survey (USGS). This scientifically realistic scenario imagines a 7.0 moment magnitude earthquake occurring on the Hayward Fault and presents the potential hazards that would accompany this event with a strong focus on effects to infrastructure and economy within the region and across the country (25). In great service to this project, the HayWired Scenario allocates significant attention to the region's reliance on telecommunications, allocating a monumental volume to analysis of the effects of a major earthquake on virtually all formats of voice, data, and text connectivity, alongside the societal consequences that could accompany the anticipated digital disconnect (24). Beyond the obvious opportunity for a titular telecommunications pun, the reason for this emphasis lies in the fact that the United States has not experienced a high-magnitude earthquake in an urban center since the Internet embedded itself as an indispensability in our society and culture. The geographical backdrop for this scenario is no coincidence as the Hayward Fault is long overdue for a major earthquake and inconveniently passes directly underneath the campus from which this project materialized.

Analysis of historical data reveals that the Hayward Fault has experienced a 6.3 magnitude earthquake every 140 years on average. As of the publication date of this thesis, 155 years have passed since the last major activity on the Hayward Fault. A passing review of the quantified impact of the 6.8 magnitude 1868 Hayward Earthquake might leave an optimistic outlook for the potential impact of a future earthquake. With only thirty lives (tragically) lost and an assessed

$350,000 in property damage ($7.5 million in 2023), one might be tempted to underestimate the potential impact of future seismic activity in the region (23). It bears considering, however, that at the time of the earthquake, Alameda County's population hovered somewhere around 15,000 people, a number that has grown significantly to its most recent census count of 1.7 million (10, 27). USGS estimates believe that the next earthquake on the Hayward Fault presents a threat to 7 million individuals and 2 million buildings, in addition to countless infrastructure elements, utilities, and economies spanning digital and analogue worlds. While we cannot accurately predict the timing and intensity of this impending disaster, we can assuredly predict that it will have a momentous impact on the people, infrastructure, and economies of Berkeley, Oakland, San Francisco and surrounding areas.

The most pertinent conclusion from the HayWired Scenario analysis may also be the least considered among the public; in the aftermath of a high-magnitude earthquake, voice and data services will go virtually offline, serving less than 10% of customers, while demand increases tenfold (25). While variables in impact of physical damage to infrastructure, outbreak of fires, and availability of utility technicians all factor into recovery times, access to these services may remain inconsistent or unavailable for hours, days, or weeks. In the words of the author's of the report's Societal Consequences volume, "For a population that is accustomed to using the internet and mobile data to manage their lives, the impact of service outages will accentuate the emotional and mental challenges of an earthquake" (24). For the countless individuals without a coordinated earthquake plan with family, friends, and community, it may be too late to synchronize meetup locations, family pick-ups, and basic status updates via the devices that drive our daily lives.

While the specific combination of contexts introduced in the HayWired Scenario are unique to Northern California, the susceptibility of communication infrastructure to disaster has been a reality since the invention of the telegraph. In response to this reality and the innumerable circumstances that demand distributed and resilient communication, a variety of technologies have emerged to provide connectivity even in the most inaccessible situations. The most visible solution providing remote and resilient communication looks to the stars to overcome terrestrial obstructions. Satellite communication, often used by military, emergency responders, and other off-grid endeavors, routes voice and data communications through networks maintained by distributed

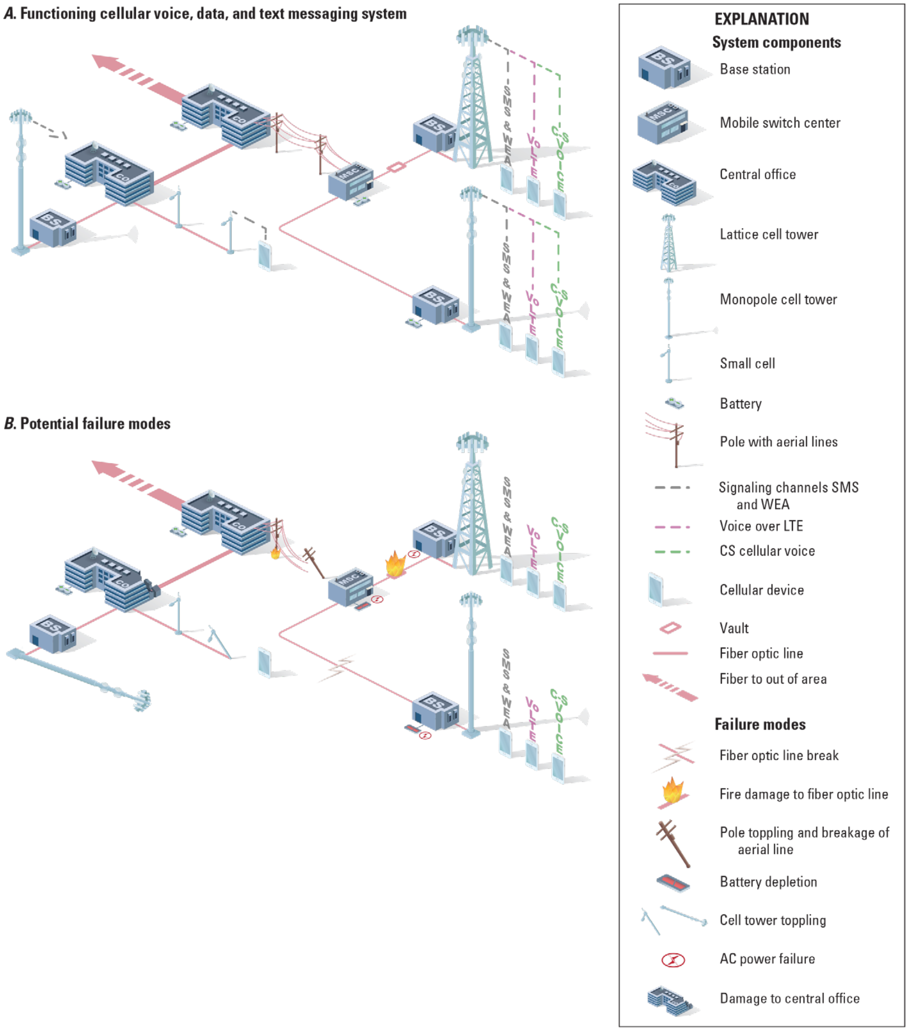


Figure illustrating the potential failure points in a cellular voice, data, and text message network resulting from a high-magnitude earthquake. Source: *The HayWired Scenario*

low-earth orbit satellites, enabling communication anywhere in the world. Expansions in civilian access to satellite communications offer a promising path forward in enabling disaster-resilient communication, but the complexity inherent in the technology's design all but ensure cost will prohibit widespread access. A recent breakthrough innovation can be found in the Emergency SOS service integrated into new iPhones, allowing users to text emergency services when disconnected from cellular or WiFi coverage. This service enables participants to connect to one of 24 low-earth orbit satellites in the GlobalStar satellite network (1). Due to the recent introduction of this offering, it is difficult to assess performance in a large-scale disaster, with hundreds or thousands of users attempting to connect through the same frequencies and satellite gateways. Prior to this recent development, consumer-focused satellite communication was largely controlled by the outdoor technology company, Garmin. Offering a variety of products designed for communication, mapping, and emergency use in outdoors scenarios, these devices provide satellite communication through the Iridium satellite network, connecting users to Iridium's 66 low-earth orbit satellite gateways. Dependent on hardware that costs hundreds of dollars and satellite subscription rates starting at $15/month, these services also fail to provide an affordable and accessible solution to audiences across the socioeconomic spectrum.

A compelling emergence from the Internet of Things movement has been the proliferation of communication technologies and protocols that enable devices to communicate over long distances. The visibility of consumer electronics has brought some of these protocols like Bluetooth Low Energy (BLE) and ZigBee into the arena of public awareness, while others, like LoRa, primarily appear in industrial applications. LoRa (Long Range) radio technology has emerged as a compelling option for infrastructure-less communication. Operating on non-licensed frequency bands (915 MHz in the US), LoRa is ideal for sending low-bandwidth, low-power communications across long-distances. While the range of these communications is largely dictated by environmental factors, the communicable distance can be substantially increased through software reception and repetition of data packets and deployment of hardware repeater units, routing messages across devices to the intended recipient.

Power outages, fire, and shaking damage to physical infrastructure are just some of the factors contributing to telecommunication disruptions during an earthquake. Accordingly, decentralized and infrastructure-less communications networks offer a more reliable and resilient alternative to conventional infrastructure-based telecommunications (22). Meshtastic and Disaster.Radio are two civic technology projects leveraging LoRa technology to facilitate communication as an alternative to traditional telecommunication networks. As the name implies, Disaster.Radio focuses specifically on post-disaster use cases, while Meshtastic takes a more general approach to off grid, decentralized, general purpose mesh networks. Meshtastic provides a particularly compelling offering in its active developer community, wide-ranging hardware support, and integrated encryption (22). Similar product offerings have emerged in consumer electronics space, most notably GoTenna Mesh, a consumer-focused hardware and software bundle. Partially founded in response to the communication impacts caused by Hurricane Sandy in 2012, GoTenna performed a commendable deployment of a mesh-based communication network in the aftermath of Hurricane Maria in 2017 (5). Despite compelling achievements in long-range radio communication, widespread adoption of the GoTenna has been hampered by the platform's use of proprietary radio technology that limits communication to other GoTenna users. During the course of this thesis GoTenna Mesh took its consumer division offline, completing a long-term redirection of the company's priorities towards law enforcement, military, and professional emergency resources.

One of the most meaningful technological advancements to have emerged from this domain in the last several decades has been the rollout of the ShakeAlert Earthquake Early-Warning System. While technology doesn't exist to anticipate when and where an earthquake will strike, earthquake early-warning systems use extensive networks of seismic sensors that detect compressional (P) waves, the fastest-moving waves released by an earthquake. When the system is alerted to the presence of the P-wave, an alert is sent out at a faster rate than the speed of the stronger but slower transversal (S) waves, the waves that elicit shaking (4). Through advanced automated notification systems and high-speed data, the arrival time and strength of the earthquake are estimated and shared to those connected to the notification network. While the system is still in its infancy, it provides an unprecedented level of notice around the imminent arrival of large earthquakes. Through strategic integration, seconds of notice can enable automation of life-saving reactions in public transportation, building systems, and hospitals (6). Berkeley's proximity to the Hayward Fault would present a complication in the amount of notice that could be received through this system, but with proper education and planning, every second can make a meaningful difference. Earthquakes on the neighboring San Andreas Fault, Calaveras Fault, and Concord Fault would provide more advanced notice, as recently experienced by residents of the Bay Area in advance of the 4.2 magnitude tremor that struck Millbrae in October 2023 (13).

"Only structures of first-class design and materials and honest workmanship could survive. Flimsy and loosely built structures collapsed like houses of cards under the terrific wrenching and shaking, and many of the structures which withstood the earthquake were subjected to a second test in fire…"

1906 San Francisco Earthquake (26)

Hoyt, Henry A. *Family in Front of Earthquake-Damaged Santa Rosa Home*. April 1906. JSTOR,

Motivation

History has taught us that the most vulnerable members of society are the most impacted by instability, uncertainty, and disaster; earthquakes are no exception (10). While earthquakes do not discriminate, the effects of an earthquake are invisibly skewed by socioeconomic differences. Of the 63 deaths that occurred in the 1989 Loma Prieta earthquake, 42 of them took place in West Oakland, a historically Black neighborhood that has been the subject of structural marginalization for decades. A key contributor to this tragedy can be found in the literal foundations of West Oakland atop landfill, a condition that resulted in sinking of soil and collapse of buildings when the shaking began (6).

The intention behind facilitating access to this project by way of local public-school systems aligns with the motivation behind my project in two important ways: First, to make this system available to users across socioeconomic classes, and secondly, to connect with students as a captive and receptive audience, who can integrate these practices into their lives into the future, implanting a range of earthquake preparedness into community consciousness. The HayWired Scenario estimates that 350,000 individuals considered socioeconomically vulnerable live in areas likely to sustain concentrated damage, and more than one million school-age children reside within the region that will be impacted by the Hayward Fault (24).

Public health education through schools taught children to cough into their sleeves, and the children taught the adults. Fire education school programs teach children to stop, drop, and roll, and the message embedded into the community's collective consciousness well into adulthood. (12) Though technology and globalization over the past century have enabled profound advancements in visibility into the effects of disasters to the point of established indifference to those suffering, and the effects of climate change are only expected to increase the frequency of these natural emergencies and disasters (20). There is no short-term, simple solution to impressing upon the public the importance of earthquake education and preparedness, but recurring and repeated earthquake training into school curriculums in earthquake-prone regions provides a pathway for actionable and targeted lessons. When children bring these lessons home, they proliferate through the household in ways unachievable among other demographics. By integrating the education, creation, and deployment of this platform into primary school emergency communication platforms, this technology has the power to reinforce existing communication pipelines while enabling a resilient alternative lifeline when conventional telecommunications fail.

“When the quake died down, the kids got up from under their desks, and put their seat cushions on their heads. Everyone filed to the playground… What shocked me was that the kids were so calm about it all. I guess they were well prepared.”

2011 Tōhoku Earthquake (11)

Steve McCurry. *JAPAN. Kesennuma. May 2011. Destruction after an Earthquake.* JSTOR

Method

My initial approach in this project anticipated a centralization around the intersection of technical and educational methodologies. However, as I further familiarized myself with existing academic foundations of the psychological hurdles around disaster preparedness reinforced by empirical observation, I began to identify a variety of more complex characters involved, including accountability, socioeconomic injustice, and community empowerment.

How do you find an audience who cares enough to participate?
My research repeatedly revealed the paralyzing effects of indifference as an overpowering hurdle in achieving credible advancement in this domain. Either due to lack of awareness around the impending threat of high-magnitude earthquakes, lack of education about earthquake preparedness, or lack of first-hand experience with earthquakes, there are a variety of attributable sources for the prevalence of apathy. In the aftermath of an overestimated ShakeAlert notification on October 18, 2023, I circulated a survey to my peers with questions assessing success rate, emotional response, physical response, and general earthquake preparedness, and received a polarizing response. Recipients of the alert either froze in fear and anticipation of impending death or casually dismissed the alert with little concern for the possibility of any meaningful effect. Consistent across all reactions, however, was a candid acknowledgement that they had no earthquake plans, preparedness, or precautions in place prior, before or after the alert. After sitting through comprehensive presentations on earthquake warning systems, earthquake preparation, and potential damage, my peers seemed unaffected and unconcerned when given seconds of warning in anticipation of a "Severe" incoming earthquake. Despite minor bruises to my ego, this observation provided a clarifying reminder that education alone would not elicit action among the general public. However, In the aftermath of the regional frenzy resilient from the ShakeAlert, I found

an increased interest and engagement in my research and conversations with a population that aligned with my project's focus on vulnerable populations; parents with primary school children repeatedly emerged as concerned and willing participants to discuss my research and engage in potential solutions.

By focusing on primary schools, parents, and children, this project aims to establish an emergency communication network in a system in which accountability carries credibility, while simultaneously conditioning disaster preparedness into children, an audience that is generally more open to instruction and authority than adults. As accustomed participants in systems of primary school administrative practices, authorized emergency pickup procedures, convoluted carpool routines, and ad-hoc and arranged community networks, the shelter of the involved parent revealed itself as a seismically-sound foundation on which a community-focused network might succeed.

How do you establish trust in a decentralized, ad hoc network whose existence depends on the cooperation of its users?

While the decentralized and distributed nature of an ad hoc mesh network is a benefit in mitigating the effects of earthquake damage to fixed infrastructure, these characteristics don't engender trust on behalf of users, who may wonder whether the network will be active enough in their moment of need. This project addresses this discrepancy through the use of a two-component model. The first user-facing component prioritizes flexibility, low-cost, and mobility. A second behind-the-scenes component serves as a school-maintained stationary system supporting a backbone network, providing potential users with confidence in the availability and stability of the network during a true emergency.

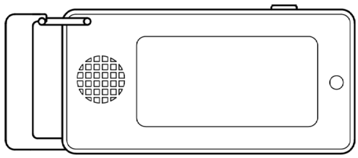
Initial hosts for this backbone network initially centered on local Community Emergency Response Training (CERT) programs, developed by the Los Angeles Fire Department in response to the success of community disaster response in Japan and Mexico in 1985. Over the past decades, CERT has expanded across the United States, and a unified curriculum has been developed by FEMA. By enrolling in the Oakland Community Response Training program, I gained access to the comprehensive federal and regional resources distributed through the CERT program. While CERT plays a meaningful role in formalizing community disaster response, the ad-hoc and informal involvement of

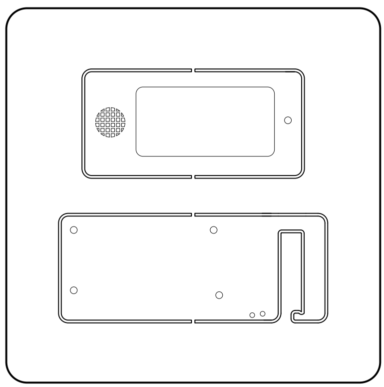
CERT as a community resource did not provide a firm foundation on which to establish the system. (16) While early research around CERT involvement revealed the importance of distributed physical facilities that could house, power, and maintain network activation and assurance hardware, anticipations of already-strained first responder resources during an earthquake removed formal authority systems from consideration.

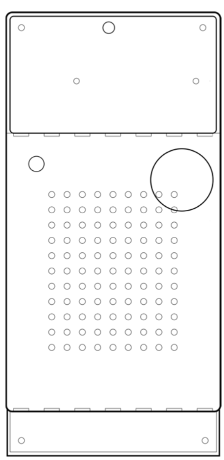
Through the CERT training program, I encountered FEMA protocols for school safety programs and successful experiences of community response programs integrating into school curriculum in remote unincorporated cities. These case studies emphasized that the primary school context has a unique combination of structure, distribution of maintained facilities, and a responsibility to teach and safeguard some of society's most vulnerable populations. It also became clear that recommended protocols for school disaster response acknowledged anticipatable disconnects and societal responses to natural disasters but offered little in the way of concrete solutions, leaving opportunity for integration of participation and reinforcement of emerging solutions. (9)

How can this solution be accessible across socioeconomic demographics?

Maximizing access to this system is achieved through three key steps. The first strategy is the establishment of community participation. By integrating the setup and assembly of the Mobile Unit into earth science syllabi, students and parents participate in the physical and emotional process of creating their network. Pulling from processes of participatory politics and community-based disaster management, this process establishes agency among the participants, and highlights the value of non-hierarchical and decentralized cooperation for the creation of new mechanisms for community response and support (18). Secondly, by keeping the cost of the hardware componentry down, this project hopes to offer a financially feasible platform for connecting vulnerable populations. Products built on similar technology have been identified in the $100 - $300 price range. By offloading complex elements of the system to the Stationary Unit, simplifying the componentry and production elements, and offering the product as a user-assembled kit, the proposed Mobile Unit can be produced for less than $50. While this cost is negligible relative to the potential trauma caused by the disconnect of an earthquake, the modular kit format also enables the opportunity to deconstruct and re-distribute kits as students move between schools or leave the school district. A second element Lastly, the public school as distribution network model seeks to cut out the socioeconomic elements from access. Engagement with the platform is less dependent on class variables like household income, parental availability, or internet access, and instead takes place during school hours, supported by municipal funding.







Final Design

The [Tech]tonic Toolkit is primary experienced through the student-assembled mobile unit (SaM). SaM is a flat-pack, user-assembled kit consisting of 12-pieces that combine to create a portable mesh-network communicator. Once assembled, the electronics are housed in a compact aluminum encasing that provides resilient protection of the inner workings while retaining a comfortable, lightweight form-factor. The kit contents include:

1. Aluminum faceplate and backplate
2. Motherboard
3. LoRa board
4. E-Paper Display
5. Li-ion Battery
6. BLE Antenna
7. LoRa Antenna
8. Button
9. Assembly screws
10. Assembly tool

The software powering the [Tech]tonic Toolkit is a customized configuration of the open-source Meshtastic platform with a modified device firmware pre-flashed to the device. Students assemble the components following the 16-step procedure illustrated in the user manual. In alignment with Next Generation Science Standards (NGSS) in Earth Sciences and Engineering STEM curricula, this kit has been designed for 4th grade students in seismically active regions. Alongside instruction around regional seismic patterns and earthquake preparation and response, students will be assigned assembly of the toolkit as an assignment. Students can either build the toolkit in-class or at-home as an assignment. Once constructed, the class will learn how the assembled messenger connects to the school system, along with basic understanding of radio technology.

Final Design of the assembed [Tech]tonic Toolkit mobile unit


BUSD
Detected, Berkeley
Network Activated
RAK

The bright colors and simple visual design utilized in SaM's faceplate and bumpers are meant to provide a visible but friendly appearance without appearing juvenile. The modular nature of the faceplates, bumpers, and buttons allow students the option to swap and exchange parts to customize their communicators. The powder-coated aluminum exterior and plastic bumper ensures that the internals will resist the day-to-day bumps and bruises, and the integrated clip is designed to attach to backpack, purse straps, and zippers, keeping the communicator at arm's reach but out of the way. An alternative backplate integrates magnets for positioning on the refrigerator, white board, or other easy-to-recall location. The integrated 1200 mah lithium-ion battery provides up to 10 days of power. Future versions hope to integrate a solar cell to further extend battery life.

Configurations

The SaM unit can be configured in a one or two-device arrangement. In a single-device setup, the device will be assembled by the student and utilized by their parent to receive incoming emergency notifications from the school district's emergency notification system. Conventional emergency notification pathways like SMS and email will be supplemented by a mesh delivery option to ensure message delivery even in the absence of conventional telecommunication networks. Emergency notifications will be posted to a private School District Emergency channel only accessible to invited users.

A two device-arrangement offers access to a secondary private channel accessible only to the two paired devices, with a software designation of a parent unit and a child unit. In a two-device configuration, the parent unit offers Bluetooth pairing, allowing the parent to connect to the unit from their smartphone and send messages to their child over the network without relying on voice, text, or data networks. The child unit is only able to receive messages from the parent unit and offers no Bluetooth pairing. While configurable preset responses may be considered in a future version of the program, special consideration would need to be given to potential psychological effects of a non-responding child unit in event of an emergency, and in ensuring no child data is collected or shared.

Stationary Unit

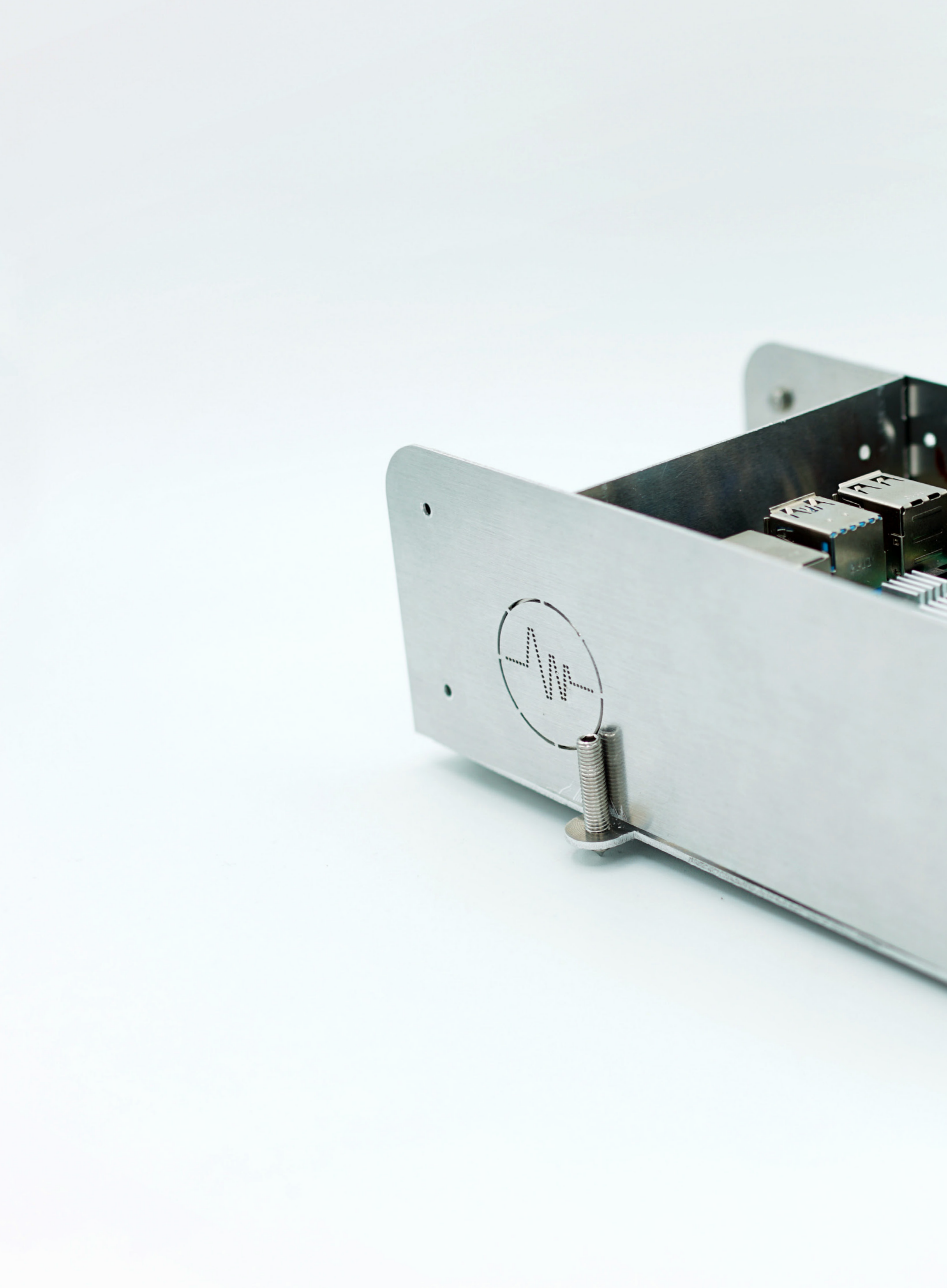
Behind-the-scenes, each school campus in the school district maintains a Stationary Unit on-premise. The Stationary Unit is composed of the following elements:

- (2) Raspberry Pi Computers
- Vertical-component velocity transducer
- 3-component (vertical, north-south, east-west) accelerometer
- LoRa Radio Bonnet
- LoRa Omnidirectional Antenna
- Weatherproof enclosure
- Battery backup

While the Stationary Unit maintains the same visual aesthetic as the Mobile Unit, the Stationary Unit is not intended for consumer use. It will be maintained by school technical administrators.

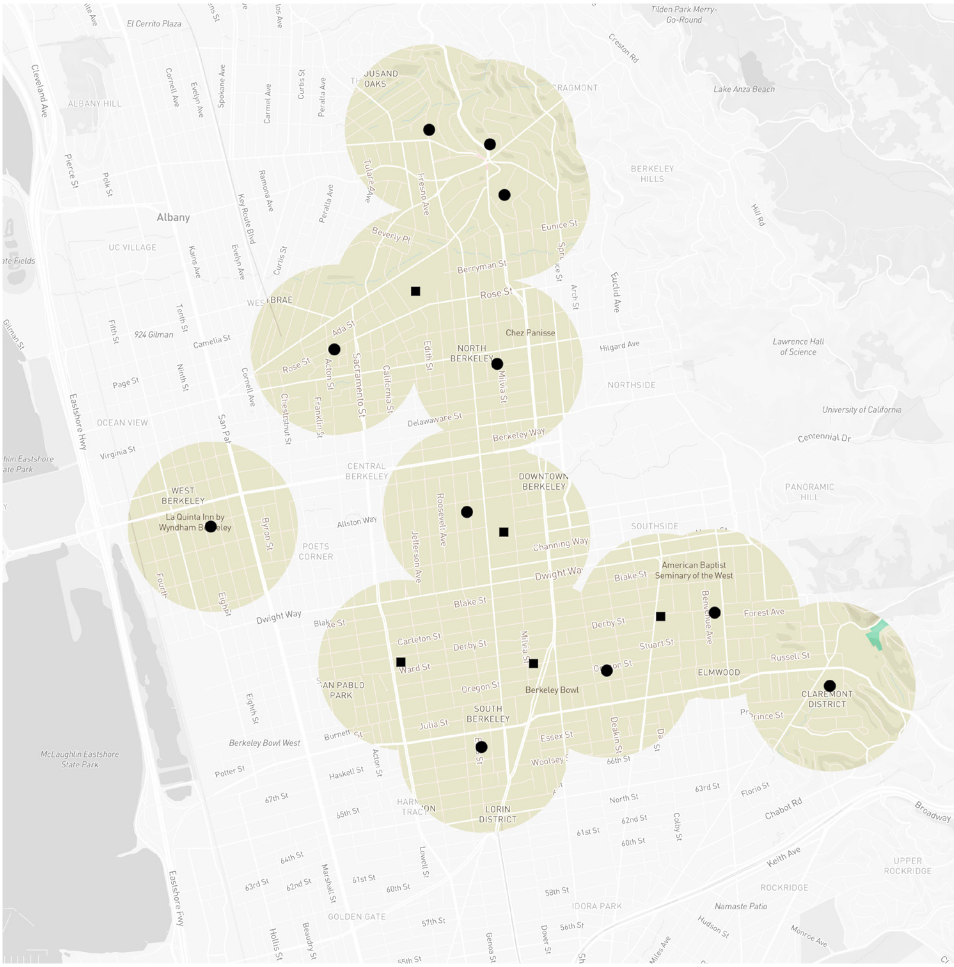
The primary function of the Stationary Unit is to ensure the establishment of a backbone mesh network in the event of a disaster. The on-board Raspberry Shake seismograph monitors for local earthquakes. Following the guidelines established by the USGS ShakeAlert system, if a 4.0+ earthquake is detected, the Stationary Unit activates the on-board LoRa bonnet and begins collecting and repeating incoming messages sent over the 915MHz channel. In the event of the power outage, an automated message will be circulated across the network announcing the system's activation and communicating the measured intensity of the triggering earthquake. Based on the geographic layout of campuses in Berkeley Unified School District, a single Stationary Unit positioned at each BUSD campus would cover almost the entire city of Berkeley with a usable mesh network. The School Earthquake Channel will be established as a priority network, but distributed Stationary Units can be utilized by anyone within range to communicate over public and private channels. In the event that there are latency issues or signal interference on the network, traffic on other channels will be deprioritized to accommodate the School Earthquake Channel.

As a failsafe, the Stationary Unit is also activated in the event of a detected power outage. In the event of power outage, the Stationary Unit will switch to battery power and deploy a notification over the on-board LoRa radio. In the event that the power outage is a localized disruption, other Stationary Units will not activate, and the notification will hit receivers in the immediate area, but quickly expire. However, if the power outage affects multiple Stationary Units, the message will be communicated across the entire mesh. The figure on the next page

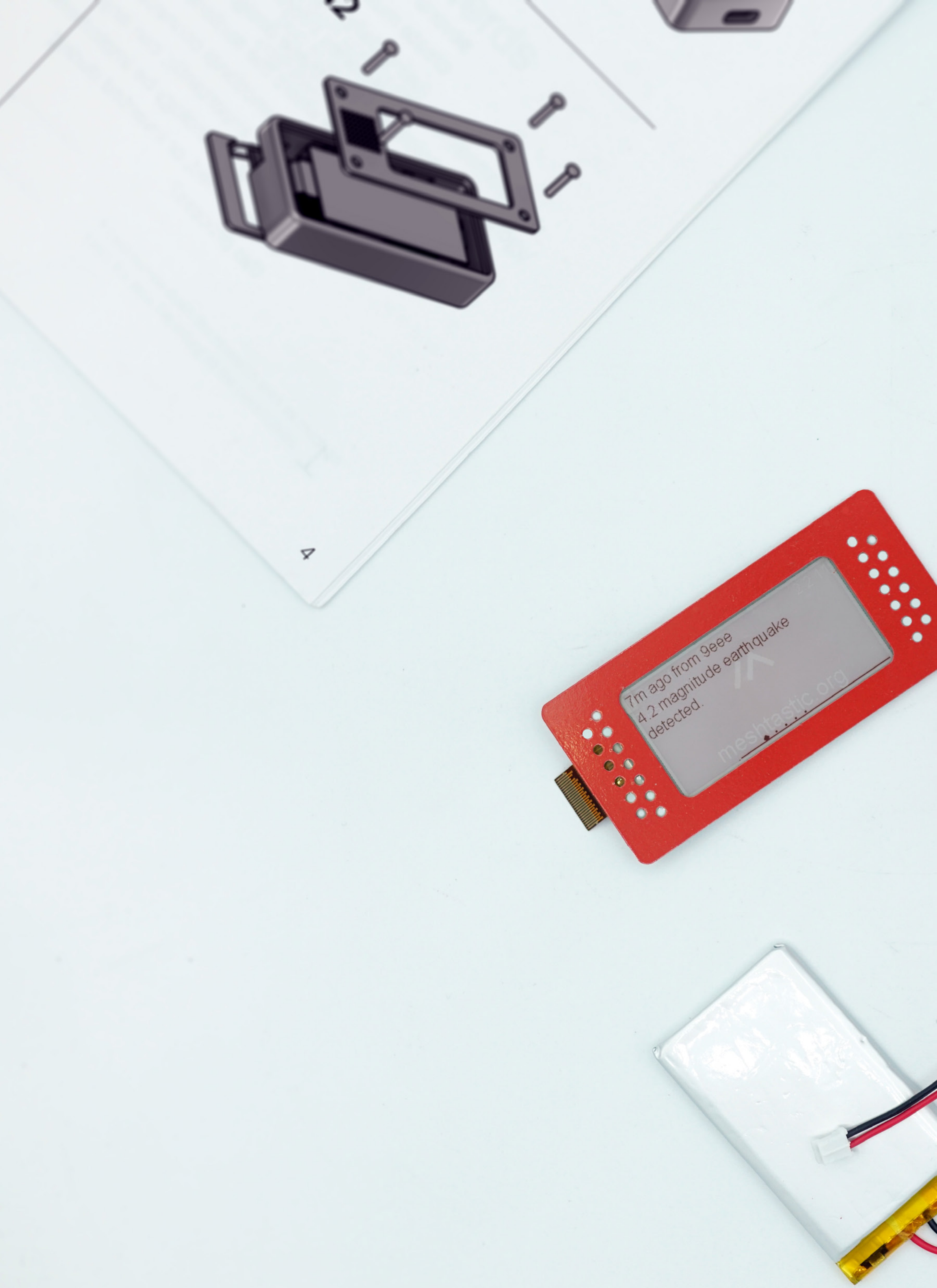


Final design of the assembed [Tech]tonic Toolkit stationary unit revealing internal components

illustrates the coverage provided by a single Central Unit at each Berkeley Unified School District location. This is referred to as a backbone network because it is a fully operational network with no additional extension or reinforcement provided by Mobile Units. Any additional units added to the network would serve to strengthen the mesh, providing more opportunities for connection and repetition of data packets.

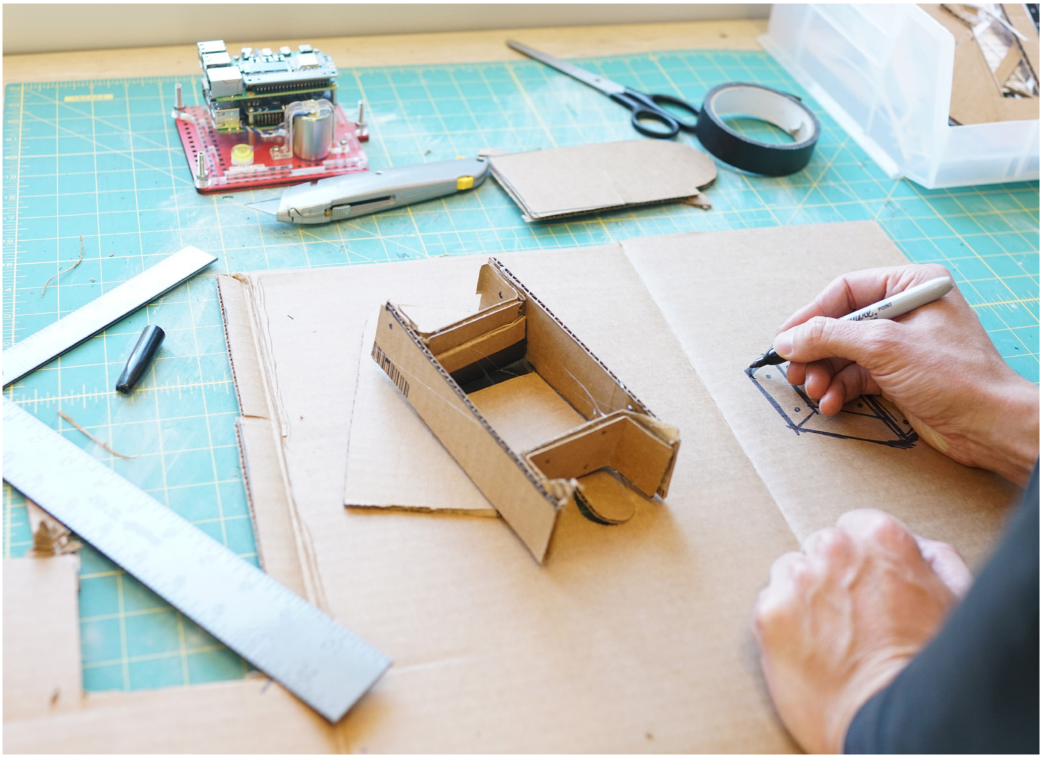


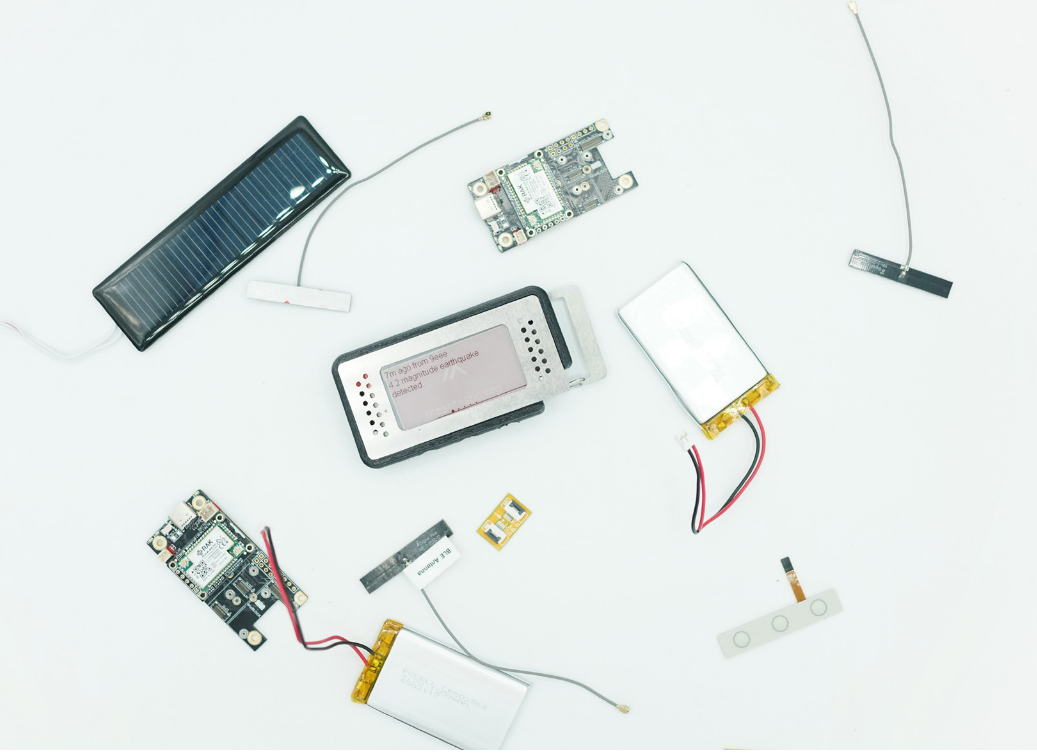
A conservative depiction of the backbone network established through deployment of stationary units in Berkeley Unified School District campuses. Activated mobile devices will extend the network range by repeating received signals.



Earlier version of the student-assembled mobile unit with internals visible


[Tech]tonic Toolkit
Parts and Assembly
RAK
RAK4630




7m ago from 9eee
4.2 magnitude earthquake
detected.
meshtastic.org
BLE Antenna


Meshtastic 3110
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Signal: 45%
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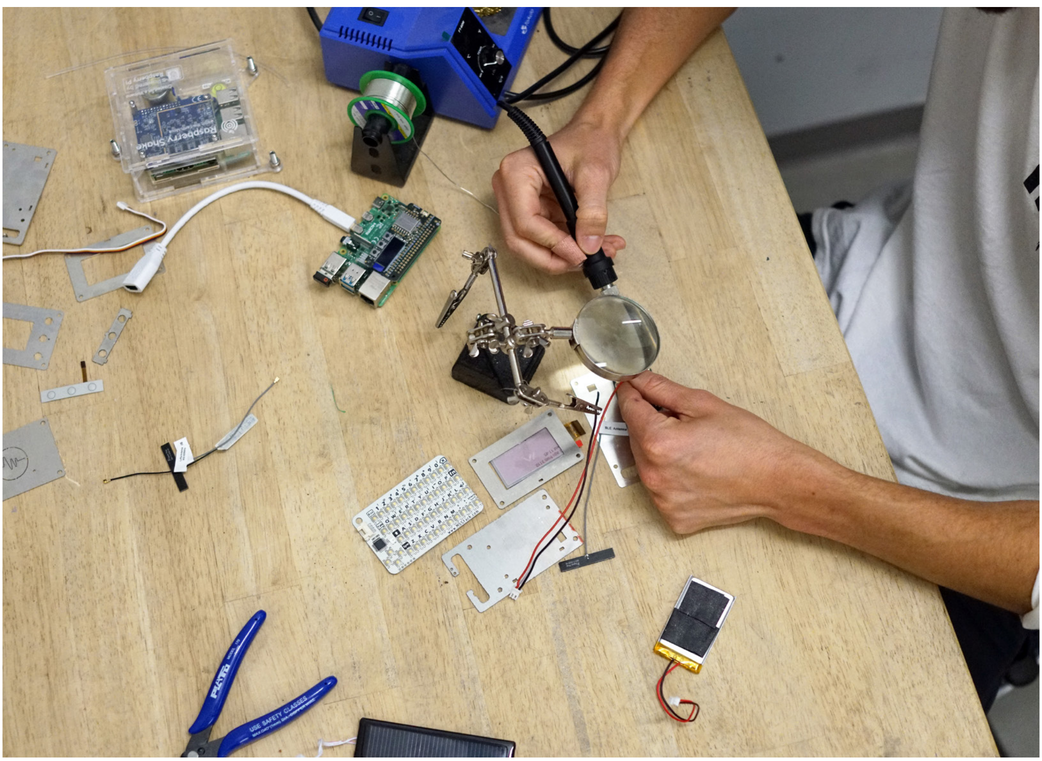
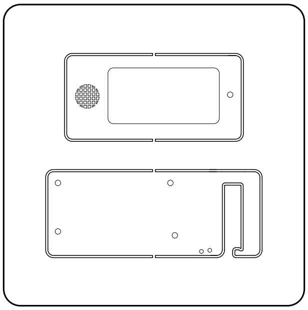
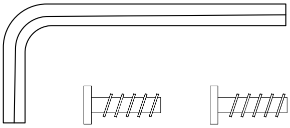
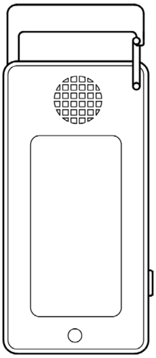




Students receive toolkit
Cost funded by school, integrated into curriculum.



Students assemble toolkit
Builds understanding of engineering and environmental science.



Parent + Child receives tool
Activate in event of earthquake.

Discussion

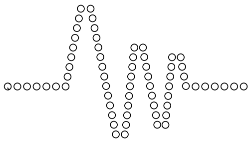
Initial reception of the [Tech]tonic Toolkit has been positive. Due to the reality of earthquake risks, this project sought to avoid functionality in the device narrative that could not be achieved in my physical prototypes. This desire to achieve promised functionality initially resulted in the exclusion of the child unit out of concern regarding the child's privacy, and inclusion of a rotary encoder that could enable preset messages was removed because of time-restrictions. However, in conversation with thesis reviewers and peers, the ability to enable communication beyond school and parent to encompass parent and child provided a monumental increase in value proposition in engaging parents emotionally. As a result, communication between parent and child was reimplemented through the use of a unidirectional private channel.

Despite initial reticence around the idea of maintaining a device specifically dedicated to the eventuality of a major earthquake, ongoing testing has revealed that users found the tangibility of the device served as an impetus to more concretely visualize how they might respond to an earthquake and served as a launchpad for developing a more comprehensive and considered earthquake plan. While the users also downloaded the companion application that enabled them to send more complex messages through the Portable Unit, the lack of a visual presence of the app in their daily routines reduced its impact compared to the physical device.

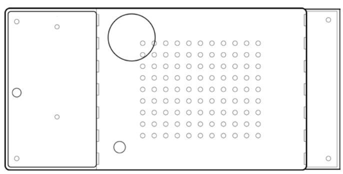
The form of the device proved particularly engaging to surveyed users, with minor details like the integrated clip and integrated magnets decreasing perceived resistance to the idea of carrying around a device specifically for an eventual emergency situation. The refined visual design successfully engaged both parents and children, with the latter group particularly engaged with the E-paper display, an underutilized technology that enables dynamic information communication alongside remarkable battery efficiency.

Critique feedback also introduced the idea of open-sourcing the product's design, a compelling idea given the product's reliance on existing open-source and civic technology projects, like Meshtastic and Raspberry Shake. While widespread adoption of the design may be limited by general access to tools metal CNC tools like those utilized in the creation of the prototypes, a worthy future path may be the creation of a variant producible though 3D printing alone. In a similar manner, programming of the Stationary Unit revealed shortcomings in the execution of the processes that enable integration of python scripts with incoming seismic data. Code enhancements are being contributed back to the Raspberry Shake community to simplify future software integrations with live seismic data.

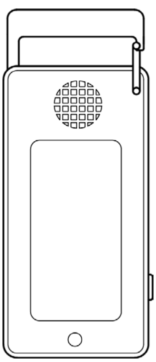
Lastly, several initial users have commented on the viability of pursuing grants or funding for a pilot deployment of the system in collaboration with a local school district. This would be an incredibly compelling next step for the project to refine the toolkit's components and assembly steps, but also to consider how the device might be integrated into other emergency scenarios or routines to extend its utility.



Earthquake detected
via onboard seismograph



Automated 'Network Activation' message
via stationary unit



Additional units join,
expanding the network

Future Work

Future envisionments for this project would seek to further simplify the form factor of the consumer-facing components while increasing the intelligence integrated into the Stationary Unit. A promising expansion would be integration of the ShakeAlert Earthquake Early Warning System, enabling the Student-assembled Mobile unit to provide advanced notice of incoming seismic activity. Due to the prioritization of range over speed in current prototypes, ample field testing would be required to ensure that early warning systems are technically compatible with the rate of transmission over Long Range Radio.

Limitations in the underlying software may also present latency issues when handling large numbers of units in a concentrated space. While Meshtastic serves as a suitable underlying software for proof-of-concept, prototype, and pilot purposes, the underlying software should be evaluated or enhanced to ensure compatibility with the technical demands of the deployment region, with particular consideration for the number of students connecting to the network.

Lastly, there are inherent contradictions in designing a system intended for widespread accessibility and modeling its deployment off of the school district of one of the country's most affluent school districts. Future iterations of this project should evaluate deployment strategies in various urban centers, ensuring that the LoRa radio range is compatible with environmental variables found in other regions.

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Conclusion

Over the course of this project, our community bore witness to a variety of tragic natural disasters, at home and abroad. Images of destruction and devastation unleashed by earthquakes in Syria, Turkey, and Morocco, fires in Hawaii, and flooding in Libya provided catastrophic reminders of our futile exertions to tame the power and potential of nature. Against the backdrop of these recurring reminders, further repeated by the constancy of 24-hour news coverage and social media, my research, surveying, and conversations continuously revealed a limitation in the ability to visualize these events impacting our community or our lives. Amidst the difficulties, distractions, and diversions of daily life, shifting user behavior patterns required a return of attention to our inner student, to the roots of our community collective consciousness and the foundations of our formations as individuals. In contrast to initial perceptions of the problem statement on paper, constructing a civilian communication network through the use of radio networks proved a forthright technical accomplishment and an arduous social undertaking.

Regardless of the success of this project, the realization has emerged that in times of disaster, the greatest hope for resilience and recovery can be found in community. Progress in this domain requires establishing a comprehensive understanding of culture and constituents. Despite the cross-disciplinary complexity embedded in this project and process, it is my hope that the underlying intention encourages analogue action, whether it be a moment spared for creation of a plan, preparation of at home essentials, or a simple introduction to a neighbor.

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