BIOSTEAD INITIATIVE: A TRANSDISCIPLINARY INITIATIVE TO CONSTRUCT SAFE-TO-FAIL GREEN BUILDINGS AS SUSTAINABLE DEVELOPMENT RESEARCH SITES ON UNIVERSITY CAMPUSES

Jose LaSalle[1], Paola Garcia[2], Ezra Marcus[3], Josh Nolan[4], Yamaan Ziade[5], Brandon Curtin[6], Michelle Nikfarjam[7]

[1]University of Massachusetts Amherst, Department of Electrical and Computer Engineering, [2,3,4]Landscape Architecture and Regional Planning Department, [5]College of Information and Computer Science, [3,6,7]Stockbridge School of Agriculture

INTRODUCTION

Mutually arising with the continuing shift in control over resources, markets and technology to transnational corporations is the need to cultivate a global system of localized economies that root economic power and environmental responsibility in self-reliant people and communities. Adopting the modus operandi of centralization has spawned a myriad of issues, including: water scarcity, food insecurity and an impending food crisis, energy injustice, vagrancy, widespread disease and inaccessible medicine, a deteriorating infrastructure, economic instability, an uprooting of ancestral livelihoods, the looting of the middle class, ecological ravage and a populace rife with spiritual suffering (Ahern, 2014, p. 2; Korten, 1996; Gunders, 2012, p.1; Hellwinckel & Ugarte, 2009; McLennan, 2006, p. 9). For instance, in the process of farm-to-fork, the modern industrial agricultural system "eats up 10 percent of the U.S. energy budget, uses 50 percent of U.S. land, and swallows 80 percent of all freshwater consumed in the United States" (Gunders, 2012, p.1). Even still, 40 percent of food in the United States is wasted while one in seven Americans experience food insecurity (Coleman, 2014). This accounts for the equivalent of $165 billion wasted each year and the single largest contribution to U.S. municipal solid waste and methane emissions at the landfill. Furthermore, most of our hazardous waste plants are disproportionately located in minority and low-income communities. To wrap it up, 1 in 600 Americans are homeless. In response to these issues, the BioSTEAD Initiative balances science with tradition to holistically address the need to organize human habitats in ways that support the right of all people to a place in society and on earth with access to the resources required to create a secure and fulfilling life for themselves, at peace with their neighbors, and in balance with the earth's natural systems. Stead is defined as both (1) a place or locality and, as a transitive verb, (2) to be of service. In this regard, BioSTEAD is a living edifice serving as a safe-to-fail research site for Sustainable Technology, Environmental and Agricultural Development. The core purpose of this initiative is to develop an open-source process for educational institutions around the world to implement climate-specific green building research sites, and to provide an academic environment for sustainable development experimentation and education, thereby serving as a model for locally-adapted regenerative practices. Our beginnings are at the University of Massachusetts Amherst; our inspiration is international.

BACKGROUND

Earthship Biotecture: Architect Michael Reynolds developed the earthship concept in the 1970s with the intention of creating self-sufficient living units. Reynolds' designs have been widely implemented, and they are rooted in six principles: (1) sustainable building with natural and recycled materials, (2) thermal mass for thermal heating and cooling, (3) water harvesting, (4) food harvesting, (5) energy harvesting and (6) contained sewage treatment. In 2007, Kruis and Heun of Calvin College published an analysis of the performance of earthship housing in various global climates. For the purposes of their study, earthships were sized to accommodate a typical family of 4 in the United States and compared to wood-framed homes. Thermal, electrical, water and financial models and simulations lead the group to conclude that earthships are a financially feasible and more sustainable alternative to wood framed housing given that some principles are compromised for municipal supplements to the utilities.

Living Building Challenge: The Living Building Challenge aims to "dramatically raise the bar from a paradigm of doing less harm to one in which we view our role as steward and co-creator of a true Living Future" (McLennan, 2006). A set of standards, called petals, governs the certification process for Living Buildings. The specifications to note are: place, net positive water, net positive energy, materials, and equity. Through the place petal, the Living Building Challenge envisions a step back from incessant expansion and a focus on connected communities, "inherently conserving the natural resources that support human health and the farmlands that feed us, while also inviting natural systems back into the daily fabric of our lives" (McLennan, 2006, p. 24). The intention of net positive water is to develop based on the carrying capacity of the site, "harvesting sufficient water to meet the needs of a given population while respecting the natural hydrology of the land, the water needs of the ecosystem the site inhabits, and those of its neighbors" (McLennan, 2006, p.30). The vision of net positive energy includes a safe, reliable, resilient and decentralized power grid, powered entirely by renewable energy in abundance. The purpose of the materials petal is to utilize non-toxic, ecologically regenerative, transparent and socially equitable resources. Regarding equity, the Living Building Challenge intends to foster a just and inclusive community regardless of background, age, class, race, gender, or sexual orientation (McLennan, 2006).

Safe-to-Fail Resilience Theory: Professor Jack Ahern of the University of Massachusetts Amherst published an article in 2011 titled *From Fail-Safe to Safe-to-Fail: Sustainability and Resilience in the New Urban World*. In this article, Ahern posits that an urban function provided by a centralized entity or infrastructure is "more vulnerable to failure" than a distributed decentralized system due to static landscape design for an unpredictable environment (Ahern, 2011, p. 5). Introducing resilience theory, Ahern describes the design perspective of "safe-to-fail" that "anticipates failures and designs systems strategically so that failure is contained and minimized" (Ahern, 2011, p.6). These systems are characterized as distributed and decentralized, biodiverse, modular, innovative, having tight feedback loops, involving social capital, and acknowledging slow variables and thresholds. Solutions for resilience, Ahern continues, therefore are more likely to evolve from such "transdisciplinary research and project-based collaborations involving an increasing number of overlapping and complementary disciplines" (Ahern, 2011, p.9).

GOALS

The BioSTEAD Initiative's designs, standards and specifications are an aggregate of those developed by Earthship Biotecture, The Living Building Challenge and The Safe-to-Fail Resilience Theory by Professor Jack Ahern. For the purpose of this study, the goals are established with regard to the environmental stewardship and basic needs of a typical American family of four. Figure 1 shows the floor plan of an earthship used as a basis for specifying the goals related to (1) space, (2) water, (3) food, (4) waste, (5) energy, (6) materials and (7) equity.

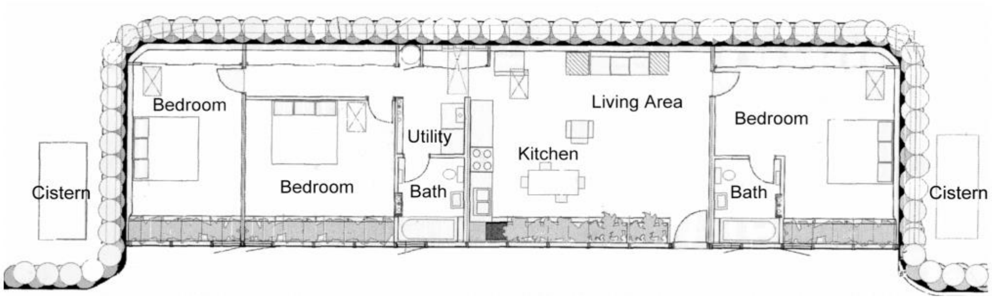

Figure 1. Earthship floor plan for three bedroom / two bath, 1990 sq. ft. home.

SPACE

- Safe-to-Fail: integrated modular systems to allow for an extensible and evolving green infrastructure of the building. Explore techniques in resilient community development.
- Thermal Comfort: operative interior temperature between 21C and 28C (70F and 82F).
- Mindfulness: realigning our understanding and relation to the natural environment that sustains us to one of symbiosis. Educational and demonstrable to the public. Center for meditation.

WATER

- Net Positive: provide potable water meeting earthship inhabitants' average use of 370L/day (Kruis & Heun, 2007, p.8).
- Mindfulness: realign individuals' use of water and redefine 'waste' in the built environment, so that water is respected as a precious resource.

FOOD

- Permaculture: create agricultural systems around natural dynamics of the ecosystem to maintain fertility, build topsoil, raise pollinators, resist pests and diseases, sequester carbon, grow super foods and be highly productive year-round.
- Medicinal: provide nutritious and healing plants for the well-being of the inhabitants.
- Local: support a web of local agriculture.

WASTE

- Sewage: all storm water discharge, including grey and black water, must be treated onsite and managed either through reuse, a closed loop system, or infiltration.
- Food Waste: composted on site and reused as soil.
- Recycled Building Materials: source locally recycled building materials.

ENERGY

- Net Positive: meet the 8kWh/day energy needs of the inhabitants with safe, reliable, decentralized and renewable power (Kruis & Heun, 2007, p.4; McLennan, 2006, p.34).

MATERIALS

- Responsibly Sourced: natural, recycled, local, non-toxic, ecologically regenerative, transparent and socially equitable.
- Artisan Guild: train responsible and skilled producers for a materials economy.

EQUITY

- Social and Economic: fair, just and equitable treatment of all people regardless of socioeconomic status, age, ethnicity, and gender. Fair trade. Open Source. Transdisciplinary.
- Environmental: employ a land ethic that affirms the right of '*resources'* (soil, water, plants and animals) to continued existence, and, at least in spots, their continued existence in a natural state (Leopold, 1970, p.239)

METHODS

SPACE: Working with Reynolds' earthship design, the high density soil inside the tires, along with earth berms on the exterior of the walls, maximizes the thermal mass of the home. Capitalizing on passive solar heating and a natural ventilation process known as the stack effect (Figure 2), the large thermal mass stores heat and stabilizes the interior operative temperature (Kruis & Heun, 2007, p.1).

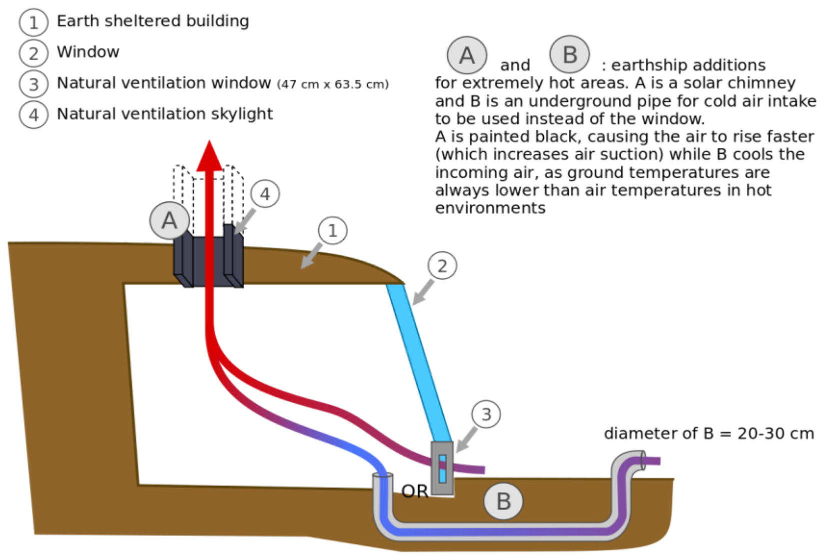

Figure 2. The Stack Effect (Thermal Draught).

The target location for this build is the Agricultural Learning Center (ALC) at the University of Massachusetts Amherst. The ALC is a 40 acre plot of farmland that serves as a hands-on, living classroom for students to learn about regenerative farming and the horticultural, nursery and landscape industries. Figure 3 illustrates the suggested position of the BioSTEAD and Figure 4 shows the location of the ALC in relation to the university campus. The extensive open land in this area allows for strategic positioning of the BioSTEAD for optimal solar gain and fertile soil for agricultural production.

Figure 3. BioSTEAD footprint at the ALC.

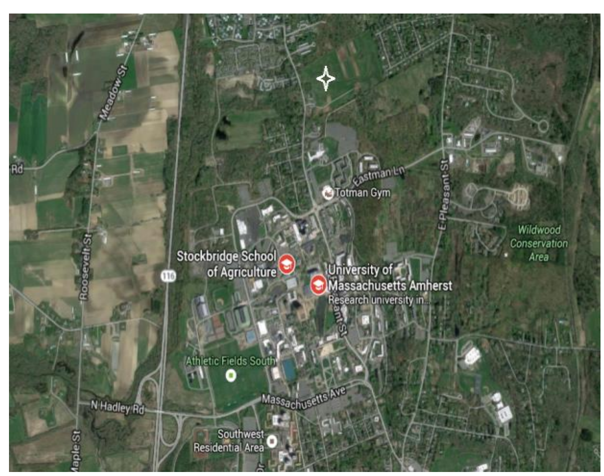

Figure 4. ALC location near campus (denoted by the white star).

WATER: The BioSTEAD's water system is inspired by the earthship water organization module (WOM). Figure 5 illustrates the earthship WOM (Kruis & Heun, 2007, p.4). Precipitation runs off the roof (1), collects in a gutter, and deposits into a cistern (2) for long term storage. Water from the cistern is pumped through a filter and into a pressure tank (3) for potable and domestic use by removing bacteria, heavy metals, pesticides, pharmaceuticals, chlorine and fluoride. Water in the pressure tank is used in showers, baths and sinks (4). Drainage flows through a grease interceptor (not pictured) and into an interior planter (5). Water not absorbed by plants gathers at the bottom of the planter where it can be pumped back into the bathroom for toilet flushing (6). Effluent from the toilet is discharged into a botanical treatment cell (7), which, in conjunction with a conventional septic tank, contains and treats the earthship's wastewater.

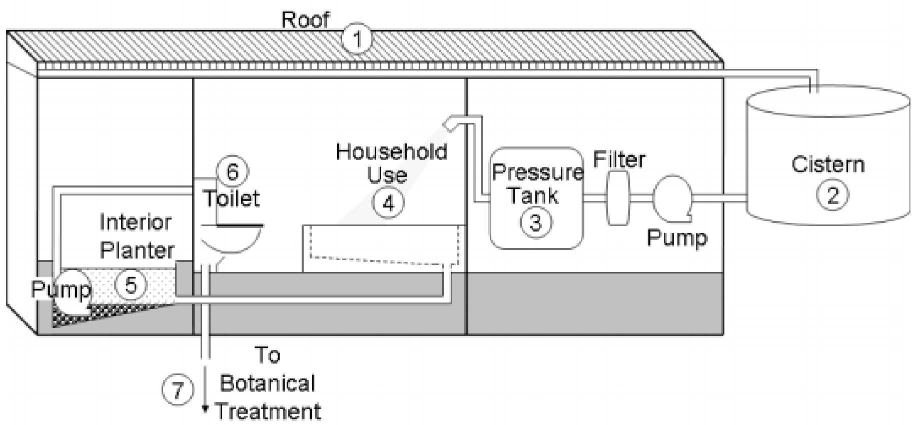

Figure 5. Earthship catchwater and greywater system.

The U.S. national average for water use is 1770 L/day. "Efficient use" is 950 L/day, and a typical earthship use is 370 L/day. Over a 1990 sq. ft. roof, a BioSTEAD in Amherst collects 592 L/day, on average (US Climate Data, 2016). For this reason, the water needs of a four person family would be sufficiently met.

FOOD: Innovative green builders and pioneers in the field of permaculture provide a foundation for achieving our goals related to regenerative agriculture. The earthship design incorporates a greenhouse in the front of the building for food production, medicinal plant growth and interior temperature regulation. As referenced in the aforementioned water system (Figure 5), a botanical garden planter exists inside the greenhouse and provides food for the household, especially super foods. To maximize the food production per unit area, half of the BioSTEAD's interior space is dedicated to regenerative agriculture and the exterior is reserved for an edible forest garden. Standards of the Vermont Regenerative Agriculture Certification Program suggest a fair template for measuring success in regenerative farming. This act, taking effect July 1st, 2016, describes these standards over a three year period to be "(1) topsoil on the applicant's land increased in each successive year; (2) the applicant's farming methods are sequestering carbon in each successive year; or (3) soil on the applicant's land contains an increasing percentage of organic material in each successive year" (2016). By integrating polyculture systems to meet these standards, a family and community can produce food and medicinals in abundance (Hellwinckel & Ugarte, 2009).

WASTE: Michael Reynolds' intention with earthships was to create self-reliant living units from sustainable or recycled materials. A typical northern hemisphere earthship (Figure 1) consists of west, north and east walls constructed using soil-packed automobile tires stacked as bricks to a height of 8 ft. (2.4 m) (Kruis & Heun, 2007, p.1). For the average earthship, this diverts from the landfill around 750 tires and hundreds of bottles and cans which are used in the framing. The water system (Figure 5) contains the sewage and composting systems recycle the food waste. The culmination of these factors greatly contributes to the decrease in a BioSTEAD's ecological footprint.

ENERGY: The primary energy source for a BioSTEAD is the sun. Photovoltaic systems follow a commonly adopted integration of technologies as illustrated in Figure 6. This system is known as the power organization module (POM) in earthships. The solar panels convert solar energy into DC electrical energy. Current from the panels flows through a charge controller that regulates the charging of the batteries, which store the electrical energy. An inverter translates the direct current (DC) from the battery bank or a generator into alternating current (AC) to power standard home appliances.

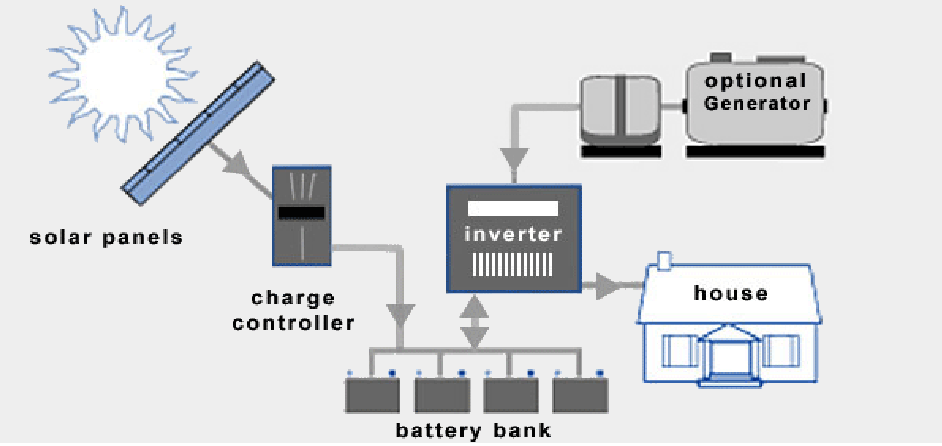

Figure 6. Solar Harvesting Sytem.

Current battery technologies, such as the 7 kWh/day Tesla Powerwall, can be configured into integrated topologies to meet the net positive energy goal of 8 kWh/day energy needs of a family of four. Future technology such as supercapacitors and zero-point energy generators will be fundamental to BioSTEADs.

MATERIALS: Just as The Living Building Challenge, the BioSTEAD Initiative envisions a future where all resources in the built environment are regenerative and have no negative impact on human and environmental health. From stone, metal, minerals and timber to tires, bottles and funding, the BioSTEAD has guidelines for conscious consumption in a materials economy stated in the goals section. Akin to the regenerative agricultural certificate for food, third-party standards exist for material procurement, such as the Forest Stewardship Council for timber (McLennan, 2006, p.46). These are useful for verification of our goals. Coupled with the conscious consumption is responsible creation of value-added products by skilled BioSTEAD professionals. Such products may be based on hemp, mycelium, lumber, recyclables, and more.

EQUITY: The social sustainability of the BioSTEAD is rooted in community involvement. In prioritizing an open and equitable platform for student, faculty and community inclusion, an intersection is formed between design professionals, decision makers and stakeholders (Ahern & Becker, 2014, p.6). Consequently, communal understanding and value of the project give rise to public support and cultural identity with the BioSTEAD. Economically, the designs are open-source and optimized for minimal cost so as to empower community members of various income level to meet their basic needs. Environmentally, all of the methods that the BioSTEAD employs affirm an inherent respect for the ecosystem.

RESULTS

Earthship Performance and Feasibility

The analysis of the performance of earthships in various global climates presented by Kruis and Heun demonstrates that these buildings are economically feasible and more sustainable than a standard wood-framed home. This conclusion supposes that the earthship will be supplemented with minimal utilities to meet the energy, water and heating needs that the house could not produce in its respective climate. For our New England climate, earthship construction is fairly novel. The closest earthship to the University of Massachusetts Amherst is owned by Amitava Biswas in Huntington, VT. From two work-visits to this build, our student group learned the advantages and disadvantages of New England earthships. The advantages include the abundance of rainfall, local materials, fair solar gain and the support from the innovative agricultural community. The main disadvantage is humidity, and an efficient HVAC system is suggested. In addition to our construction goals, our educational goals have precedence at the University of New Mexico with their earthship biotecture class.

Considerations for Implementing a BioSTEAD

Regarding the practical implementation of a BioSTEAD at a university, a number of requirements need to be met. To yield a sustained movement, an educated body of students, faculty, and community members needs to be established with regular meetings, clear and constant communication, systems of management and accountability, and a cohesive set of core values, principles, and goals. Additionally, the administration and facilities services must support the project. For example, the UMass BioSTEAD Initiative has garnered the support of the Chair and Director of Design and Construction Management, a division of Facilities and Campus Services. This support means that Facilities is willing to work with the BioSTEAD Initiative to engage the state building inspector for coming into compliance with building codes. Given the success of a build, a road will be paved for future state citizens to attain permits for the construction of similar buildings in the same way Michael Reynolds set the precedence for earthships in New Mexico. Also, it is beneficial to include the university's Campus Planning division. At UMass, the Senior Campus Planner agreed to facilitate a design charrette, the standard practice with the LEED certified green buildings on campus. A design charrette is a meeting where a group of professionals from a multitude of disciplines gather to generate a design based on a set of functional purposes, aesthetic purposes, and a palette of materials and resources. Through this process a new era of development is naturally ushered in with invitations to collaborate extending to students, faculty, facilities, and community professionals. With a focus on bridging the gap between our deep-seated roots and expansive technological advances in development, it is imperative and a high priority to include native peoples at the charrettes by virtue of incorporating indigenous building practices into the BioSTEAD. The remaining considerations regarding the construction are land and funding. The aforementioned Agricultural Learning Center at UMass is the intended location for the BioSTEAD, and permission for building has been granted. Crowd-funding is a feasible and accessible option for financing the project, and campaign platforms are offered by many universities with 0% service fees. These represent the breadth of the requirements for implementing a BioSTEAD successfully.

DISCUSSION AND CONCLUSION

A core principle in permaculture is leveraging a perceived problem as an advantageous solution. Numerous organizations have applied their diverse skill sets in unique ways to address the spectrum of issues that exist today and enact positive change. Pioneers such as Earthship Biotecture, The Living Building Challenge and Professor Jack Ahern lay the groundwork for others to synthesize and create new solutions in sustainable development. The BioSTEAD Initiative's goals have roots in these innovators, and our group applies these goals through methods regarding space, water, food, waste, energy, materials and equity. As a safe-to-fail educational site for sustainable development, the BioSTEAD serves to provide the space for researchers to determine and demonstrate feasible implementations that meet the basic needs of a typical family of four in an environmentally just way. In assessing the systems within the BioSTEAD and practices it represents, an effective and extensible process for global incorporation of green buildings at educational institutions, and surrounding communities thereafter, is conceivable.

REFERENCES

Ahern, J. (2011). From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. Landscape and Urban Planning, 100(4), 341-343.

Ahern, J. F., Pellegrino, P., & Becker, N. (2014). Performance, appearance, economy, and working method.

An act relating to establishing a regenerative agriculture certification program, 159, (2016).

Bourne, J. K. (2015). The end of plenty: The race to feed a crowded world WW Norton & Company.

Coleman-Jensen, A., Gregory, C., & Singh, A. (2014). Household food security in the united states in 2013. USDA-ERS Economic Research Report, (173)

Gunders, D. (2012). Wasted: How america is losing up to 40 percent of its food from farm to fork to landfill. Natural Resources Defense Council,

Hellwinckel, C., & Ugarte, Daniel De La Torre. (2009). Peak oil and the necessity of transitioning to regenerative agriculture. Farm Foundation's,

Kruis, N. J., & Heun, M. K. (2007). Analysis of the performance of earthship housing in various global climates. ASME 2007 Energy Sustainability Conference, 431-440.

Leopold, A. (1970). A sand county almanac: With other essays on conservation from round river Random House Digital, Inc.

McLennan, J. F. (2006). The living building challenge v1. 0: In pursuit of true sustainability in the built environment. Cascadia Region Green Building Council,

Philips, A. (2013). Designing urban agriculture: A complete guide to the planning, design, construction, maintenance and management of edible landscapes John Wiley & Sons.

US, C. D. (2016). Climate data for amherst, longitude: -72.5374, latitude: 42.3861. average weather Amherst, MA - 01002 - 1981-2010 normals. Retrieved from http://www.usclimatedata.com/climate/amherst/massachusetts/united-states/usma0009

ACKNOWLEDGEMENTS

Special thanks to core members, contributors and supporters: Louis Correra, Gilson Hogan, Hannah Smalls, Nicole Wetherell, Sigi Koko, Natalia Morales, Rachael Furlong, Rachel Caplin, Kevin Harrington, Gabe Benton, Sumedha Rao, Jillian Tomlinson, Chloe Mawn, Ayana LaSalle, Christopher Lundgren, Katharina Kowalski, Ian Back, Alex Dorr, Gabriel Sylvester, Marissa LaSalle, Derek Clougherty, Erin O'Brien, Samantha Gerdes, Tyler Barron, Emilie Jordao, Erik Wilson, John Gerber, Ezra Small, Renee Cuilla, Madeleine Charney, John Grant, Amitava Biswas, and Mark Hamin. See more at biostead.org.