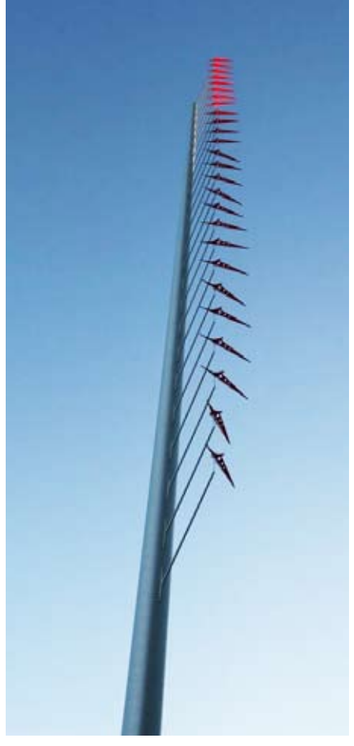

outdoor exploratorium | experiments in noticing and understanding

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contents

outdoor exploratorium | experiments in noticing and understanding

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Outdoor

Exploratorium

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The Outdoor Exploratorium Project Team, 2009

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Creating the Outdoor Exploratorium was one of the most complex initiatives ever undertaken by the museum—not only because of the project's several rewarding partnerships and collaborations, but also because the nature of the work required us to critically review (and, in some cases, fundamentally alter) our timeworn methods of creating interactive exhibits. The project's extended length meant that the core team underwent considerable change as our plans and processes evolved. So first, we note that many Exploratorium staffers and friends played a part in creating the Outdoor Exploratorium over the years. Those contributions varied widely in scope and impact, but all were vital. We thank everyone at the museum—past team members, present and former staff, those who worked with us over the long haul and those who contributed a single but powerful idea—for their creativity and patience.

As the essays and images in this publication make clear, the project was built on a collaboration between the Exploratorium and our site partners, the Golden Gate National Recreation Area and Fort Mason Center. The exhibits now installed at Fort Mason would not exist without their input and insight. We extend thanks to everyone at the GGNRA and FMC, and especially to Mai-Liis Bartling, Richard DeLaO, John Dorsey, Jay Eickenhorst, Helene Fried, Al Gonçalves, Stephen Haller, Daphne Hatch, Craig Kenkel, Pat Kilduff, Ann Lazarus, Howard Levitt, Brian O'Neill, Aaron Roth, Aleutia Scott, Joanne Wilkins, Alex Zwissler, and the staffs of the GGNRA Cultural Resources and Natural Resources Departments and the Fort Mason Facilities and Rentals Offices.

The project also benefited from the expertise and insight of an amazing group of external collaborators. We'd especially like to thank our advisors, consultants, and evaluators, including Edmund Bedecarrax, Cris Benton, Elisabeth Bouchard, Chris Burda, Carl Cheng, Dan Collins, Gene Cooper, Mark Frey, Alan Friedman, Oliver Fringer, Harold Gilliam, Hans Haselbach, Dan Hodapp, Mildred Howard, Lisa Hubbell, Ned Kahn, Ted Koterwas, Wendy Meluch, Bob Miller, J. Newlin, Bill Pottinger, Jeannene Przyblyski, Dave Reynolds, Sean Riley, Arlene Rodriguez, Patrick Ryan, John Roloff, Beverly Serrell, Mark Stacey, John J. Stachowicz, Gary Strang, Randy Tagg, Steven Vogel, Ruth Wallen, Kary Witt, and the staffs of the San Francisco Conservation Corps, NOAA, and the USGS. Finally, we thank the National Science Foundation for their support.

the project

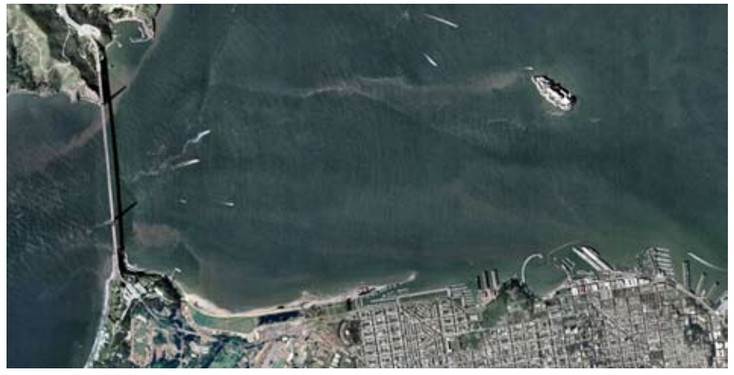
THE OUTDOOR EXPLORATORIUM AT FORT MASON: GENESIS AND OVERVIEW

Peter Richards
Principal Investigator

Exploration, experimentation, and discovery have been the Exploratorium's touchstones since the museum opened its doors in 1969. Perception is the museum's underlying theme because our understanding of the world is profoundly affected by the way we gather information through our senses. The tools we create for visitors include scientific instruments and aesthetic experiments designed to support self-directed investigations of our surroundings. Exploratorium founder Frank Oppenheimer, in his *Rationale For A Science Museum,* envisioned a laboratory atmosphere where exhibits aided people in familiarizing themselves with science and nature. Over the past 40 years, we have excelled at developing such exhibits—but with few exceptions, we've done little exhibit work outside the walls of our historic building, San Francisco's Palace of Fine Arts, a structure protected under the constraints of the National Historic Register.

Rather than build permanent exhibits adjacent to our building, we have looked to other ways of linking the content and process of science with the outdoors. For example, late Exploratorium artist Bob Miller developed his famous Light Walks by leading outdoor "noticing tours." His work suggested the rich possibilities of exhibits encouraging people to reflect on their experiences while walking around the city and countryside and to link their observations within a growing view of the interconnectedness of natural systems. For his part, Oppenheimer once described the experience of visiting a place like the Exploratorium as akin to wandering through the woods, following one's own path of interest and curiosity.

We have always had the desire to extend our investigations to "the woods" beyond our walls—and this idea was galvanized in 2001 when we received funding for the Outdoor Exploratorium exhibit project from the National Science Foundation, largely through the efforts of Kathleen McLean (Director of the Exploratorium's Center for Public Exhibition at the time) and Exploratorium Senior Scientist Thomas Humphrey. The project was designed to help visitors develop skills in noticing natural phenomena, exploring complex systems and interactions at play in an outdoor environment, and applying the principles and concepts of science to their surroundings. Almost



simultaneously, however, our Board of Trustees announced their decision to find a new home for the museum, leading to the Outdoor team's search for alternative exhibit sites that would allow a range of exploration and discovery of the phenomena of the outdoor world.

After studying a number of options over several years, longtime museum friend Helene Fried suggested that San Francisco's Fort Mason Center, a former military post on the city's northern waterfront, might be interested in our project. As a member of their Board of Trustees, she introduced us to former FMC Director Alex Zwissler, and his excitement at the possibilities provided an initial spark to our collaboration. FMC staff—including Director Ann Lazarus, Al Gonçalves, Pat Kilduff, and John Dorsey—have all been exceedingly supportive during the course of the project, and we owe them and Helene our gratitude for giving us a place to expand on Bob Miller's inspiring ideas for helping people become better noticers.

Fort Mason Center is on property overseen by the National Park Service and shared with the headquarters of the Golden Gate National Recreation Area. This raised a key

question: how could we realize the project's learning goals and promote noticing and experimentation while satisfying the Park Service's preservation guidelines? Helene felt strongly that when GGNRA staff heard our ideas for interpreting their natural and cultural resources, they would be totally supportive of our efforts. After our first GGNRA presentation, late Park Superintendent Brian O'Neill enthusiastically and publicly pledged full support for the project, setting the stage for a productive working relationship. We owe thanks to Craig Kenkel, Howard Levitt, Stephen Haller, Aaron Roth, Jay Eickenhorst, and Richard DeLaO for opening their resources and support to us. We also fondly and thankfully remember Brian O'Neill—not only for his support of this project, but for being the ultimate public servant, for insuring that the GGNRA far exceeded its tremendous potential, and for inviting us to contribute to his vision.

As we worked with FMC and GGNRA on the Outdoor project, the museum continued to search for a new home. At this writing, our negotiations with the Port of San Francisco lead to optimism that we may relocate to San Francisco's Embarcadero by 2012. The potential offered by this waterfront location has spawned considerable excitement among museum staff about new kinds of site-specific exhibitry—and the research and experimentation generated by the Outdoor project have been a wellspring of knowledge and ideas for these discussions. For example, a new initiative entitled Invisible Dynamics: The Science of a Sense of Place would study the entire Bay region to reveal key relationships between natural and built systems.

The Outdoor Exploratorium was intended to develop new approaches to exhibitry that would foster observation and create a new environment in which visitors could experiment with natural phenomena. We also hoped to contribute to research on learning by assessing how visitors noticed subtle and temporal phenomena, and to identify links visitors made between Outdoor Exploratorium exhibits and the wider world. To achieve these goals, the Outdoor team thought of the exhibits we developed at Fort Mason as new kinds of pedagogical tools that would allow visitors to directly experience natural phenomena with a less mechanistic approach than that provided by our traditional indoor museum exhibits. Our partnerships with FMC and GGNRA have made it possible for us to pioneer visitor research techniques for outdoor science learning environments, to learn new ways of integrating the arts into outdoor learning, and to implement the principles of universal design and accessible science museum practice in outdoor settings.

Two key ideas here are *observation* and *pedagogy*. As we considered the possibilities and challenges provided by the natural and cultural environment of Fort Mason, we realized that we needed to develop new approaches to creating interactive exhibits. As exhibit development professionals, we asked ourselves how we could tune ourselves to a new and different location and become better observers ourselves—so that our exhibits would help visitors do the same. In this vein, we questioned how existing environmental elements and constraints could be built upon using our own "pedagogical tool chest." This publication is designed to illustrate the ways the Outdoor Exploratorium team responded to these issues. Project Developer Bryan Connell took the lead in designing an approach that resonated with the goals of Fort Mason Center and the GGNRA. He devoted himself to devising new ways of drawing attention to seemingly mundane aspects of the environment, which, upon closer scrutiny, reveal aspects of nature and the built environment with powerful and compelling implications at a range of scales. He asked the team to think about architecture and landscape as observational instruments and pointed out that infrastructure contains a trove of information to be mined and highlighted. As this approach took hold, the Golden Gate Bridge became a giant thermometer, an Alcatraz Island bell buoy was repurposed as an experiment on sound, and a loose piling became a wave detector. Bryan taught us to look closely at the world at a human scale and allow our vision to expand from the immediate to the local, the regional, and beyond.

Photo: Walter Kitundu

Frank Oppenheimer's recognition of the need for places where people could learn about nature is no less critical today than it was 40 years ago. Many in the museum field maintain that public understanding of science has diminished in recent years, while the implications of population growth and global warming are strongly signaling that solutions lie in informed collective actions on a global scale. In its own way, one implication of the Outdoor Exploratorium is that part of the answer comes from one of our most basic instincts: a desire to connect ourselves to nature. In *Natural and Civic Place Attachment and the Relation to Pro-Environmental Behaviors in Trail and Nelson, British Columbia,* Leila Scannell suggests that "connectedness to nature is a source of hope in the endeavor to reform humans' mistreatment of the environment… If individuals have a proclivity to become attached to nature, it bodes well for pro-environmental behavior." The Outdoor Exploratorium offers a new exhibit development methodology that can bring people closer to nature, a better understanding of where we live, and—we hope—better decision-making in the future.

Tom Rockwell
Director of Exhibit Environment

The Exploratorium was never meant to be an indoor-only museum. As early as 1975, six years after it first opened, the Exploratorium began to design exhibits for an outdoor environment. Yet, with a few notable exceptions, the museum developed as an indoor institution for most of its life, primarily because our lease on a historic building didn't allow us to install permanent work outdoors. But this indoor focus changed dramatically when the Outdoor Exploratorium opened at Fort Mason in the spring of 2009.

Every public cultural building, be it a museum, symphony hall, or university, stands in relation to its external environment; for every building enclosing space, an outdoor environment surrounds it. This relationship between building, institution, and environment takes many forms. Institutional buildings can celebrate the outdoors—or turn their backs on it. They can be protective sanctuaries or brutal intrusions. They can project themselves out into the world or be designed to let the outdoor environment be a major feature of their interior experience.

In the case of the Exploratorium, there has always been an odd juxtaposition of indoors and outdoors. Outside, there is the Palace of Fine Arts' neoclassical exterior, evoking nature and the romanticism of the early 20th century view of history and art. On the inside is a dark shed, a sort of universal laboratory in which the world is recreated on hundreds of tabletops. Imagine the museum's first patrons: it must have felt odd indeed to visit one of the most beautiful and dramatic sites in San Francisco and experience the discontinuity between Bernard Maybeck's lovely, melancholy exterior and the interior's laboratory, garage aesthetic.

Throughout the museum's history, there have been many attempts to bridge this discontinuity, either by breaking out of the box or bringing the outdoors inside. (Senior Artist and Outdoor Exploratorium Principal Investigator Peter Richards' iconic *Wave Organ*, a series of resonant tubes projecting into San Francisco Bay from a lonely jetty, was one such bridge.) But the need to press on this relationship between exhibits and the outdoor environment was a key factor driving a process of institutional architectural change. Starting in the mid 1990s, the museum developed a plan to renovate and expand its Palace of Fine Arts home. As this plan encountered practical and political obstacles, we began investigating and designing for several new sites. This process has culminated in the museum's proposed new location on San Francisco's Embarcadero, currently projected to open to the public in 2012.

It was with this process of architectural change that the Outdoor Exploratorium project began. As renovation plans for our long-time home became more complex, excitement grew around the idea of a permanent outdoor site more substantial than a series of installations scattered throughout the area. In 1996, early in the process of developing architectural plans, community research indicated strong support for outside exhibits, and the Outdoor Exploratorium's original proposal to the National Science Foundation was built on the notion of a west-facing outdoor exhibit park at the Palace of Fine Arts.

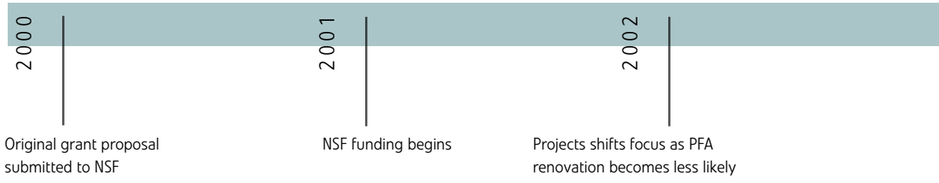
Since submitting and receiving this grant, however, broader institutional shifts forced the Outdoor Exploratorium team to fundamentally rethink its plans. As the sites began to change, plans for the Outdoor Exploratorium changed as well.

An historical overview of the Outdoor project captures what was in part a series of false starts, with project teams and museum leadership changing and numerous location-specific plans requiring alteration or abandonment. But this process, frustrating though it was, eventually led us to Fort Mason, and few of us now doubt that a stronger location (both in terms of its unique history and its breadth of explorable natural phenomena) or a more supportive and insightful partner could have been found.

In the end, we learned a number of key lessons from this long yet ultimately deeply rewarding project:

- Site selection and related negotiations are critical project phases carrying substantial risk. Perhaps this goes without saying; yet it is a lesson well-known to architects and developers who carefully balance the resources they invest in a project before they have fully secured the site. Any institution developing work for a site not yet fully secured is taking significant risks. Although all of the research we did on natural phenomena contributed to our final exhibit experiences, more than half of the Outdoor Exploratorium's project time was spent on researching locations other than Fort Mason.
- Partner sites require substantial time for collaboration and learning. Compared to installing outdoor exhibits on land adjacent to (and preferably owned by) the home institutiion, partner sites come with the need for additional research, consultation, negotiation, and approvals. Our

Timeline of the Outdoor Exploratorium Project



collaboration with Fort Mason and GGNRA was one of the project's core successes, but it did require a great deal of learning about the historic site and the integration of our own exhibit design procedures with the standards for designing in National Parks. It also came with the challenges inherent in prototyping at a distance from our machine shop, and the need to contextualize exhibits for visitors who, unlike those at a museum, may not be expecting exhibits in the outdoor landscape.

However, it's important to note that these difficulties can also be seen as the source of some of the project's breakthroughs, such as:

- The extended period of exhibit brainstorming and iterative concept development for new sites allowed the maturation of a clear exhibit pedagogy embodied in the final exhibits and articulated throughout this publication. It has also generated a large list of other exhibit and program ideas that will contribute to the outdoor site at the Exploratorium's new location.
- The project's many site investigations contributed to a vision for collaborative site-specific environmental education across multiple sites in the Bay Area. The Exploratorium is now pursuing collaborative projects with several institutions across the region as a result. This regional perspective will also be a strong element at the new Exploratorium at the Embarcadero.
- The historic National Park context and GGNRA collaboration helped introduce innovation and heighten potential future impact. The blending of two distinct interpretive cultures—the interactive science museum and the National Park Service—has led to a distinctive exhibit style that draws attention to the science inherent in the built and natural environments. This new style has the potential for broader influence on other sites through GGNRA's and the National Parks Service's networks.
- Experience with offsite investigations and partner negotiations has substantially grown the capacity of Exploratorium staff in the need and ability to collaborate with future potential partners. These skills will be especially useful as we prepare to become long-term partners with the Port of San Francisco and other waterfront agencies at our new location.

With these challenges and benefits in mind, it may be useful to take a wider view of the Exploratorium and its changing relationship to its site, the city, and the broader region. The Outdoor Exploratorium began with and paralleled the Exploratorium's process of outgrowing its current location and finding a new home. The fact that the institution's relocation was not ready in time for us to implement the Outdoor project as originally envisioned led to the need for close collaboration with a new partner. We were lucky enough to find a location that mirrored many of the characteristics of our new home, effectively giving us a site prototype and expanding the institutional vision that we are building for the new location.

For its first four decades, the Exploratorium has existed with little reference to its specific location. Through a combination of accident and temperament, the museum has functioned as almost placeless—a prototypical laboratory filled with demonstrations that could be airlifted to anywhere in the world. As we prepare for our move, both to a new site and into an era in which environmental education is taking center stage, the Exploratorium is moving from being primarily a laboratory to a combination of laboratory *and observatory*. Most broadly, observatories are site-specific windows onto the universalities of science. At our new site, the Exploratorium will, both literally and figuratively, have many more open windows than it ever has—windows onto the Bay, the city, and additional outdoor installations, but also windows providing views of the museum's growing connections with the local community and regional collaborators.

The Outdoor Exploratorium has been a crucial step in this evolution; the processes we followed, and the experiences the team and our partners created, have allowed us to learn as we do best: by experimenting, by trying new things (and, in a few cases, failing at them), and by imagining new ways of connecting people with the world around them.

2003 — Project concentrates on museum's then-planned relocation to San Francisco's South of Market (SOMA) neighborhood

2004 — SOMA site research discontinued; project siting is decoupled from museum relocation as several new sites are explored

2005 — Primary focus on Brannan Street Wharf (BSW) site in collaboration with Port of San Francisco

2006 — BSW site research discontinued; Fort Mason/GGNRA collaboration is developed

2007 — Exhibit development begins at Fort Mason

2008 — Exhibit development continues at Fort Mason; evaluation and installations begin

2009 — Outdoor Exploratorium opens at Fort Mason

SITE AND PROJECT VISION

Bryan Connell
Project Developer

Project vision for the Outdoor Exploratorium can be thought of in terms of two elements: proficiency and place. Proficiencies are the skills and abilities the Exploratorium would like to evoke in the minds of the visitors who engage with the outdoor exhibits. How successful this evocation is depends on how the site is interpreted—the degree of understanding and insight brought to the geography of Fort Mason as a place.

site vision – principles of place

With a legacy of historic military buildings and scenic landscapes, Fort Mason is a site that requires careful thought with regard to additions that might enhance or alter the value of its unique heritage. Like most urban waterfront settings, the Fort Mason landscape is also an highly engineered environment, strongly shaped by a lineage of distinctly human visions of what it could or should be. As the Outdoor Exploratorium joins this historical lineage of place-shaping, what guiding principles inform its view?

unnatural history

Traditional outdoor interpretation in National Parks, Landmarks, and Recreation Areas tends to highlight natural history and cultural history as the meaningful aspects of a place. As important as this kind of interpretation is, how do people become better observers of the more common artificial features and technological dynamics that make up so much of the contemporary urban environment? The Outdoor Exploratorium is designed to be a place where, in addition to natural and cultural viewpoints, visitors can gain a scientifically informed understanding of urban technological phenomena like the stress fracture patterns in an asphalt parking lot, or the corrosion zones that affect metal structures along the shoreline.

covert wonder

The San Francisco shoreline has many overt attractions—spectacular views, marine wildlife, famous landmarks, and historic architecture. But what about the more subtle outdoor phenomena, so easily missed but equally fascinating? For example, the oscillation of a loose pier piling in response to incoming waves, or the heat from a building wall creating ephemeral architectural mirages? The Outdoor Exploratorium's vision of the Fort Mason site is that it is a place uniquely suited for learning about this kind of covert wonder.

site as observatory, architecture as instrument

In a museum context, site and the architecture of a site are often thought of as passive backgrounds—neutral landscapes on which to install an exhibit. Can the landscape and architecture of a place become instruments, not just devices for *housing* instruments? Seen from this perspective, the subtle rising and falling of the Golden Gate Bridge span becomes a thermometer to measure daily temperature fluctuations. Rust stains in the aggregate of parking lot asphalt become markers that trace water flow patterns in the urban watershed. One aspect of the Outdoor Exploratorium's site vision is to view Fort Mason as a field guide to reading the architecture and technological infrastructure of urban environments as observation-enhancing instruments.

conjuring the ordinary

A stage magician uses sleights of hand to conjure familiar, ordinary things—matches, coins, playing cards—into intriguing and unexpected combinations that provoke curiosity and delight. Similarly, another key aspect of the project's site vision, rather than designing exotic sculptural exhibits and importing them into Fort Mason, is to rearrange ordinary elements of the landscape in provocative ways. A mundane pier piling unexpectedly lifts out of the water to reveal intertidal life. Generic sailboat mast wind indicators are combined with a common flagpole to create a wind stratification instrument. The steel door of an abandoned roadside building becomes a window into a theater of atmospheric light.

recuperation

Invisible to most visitors, many mundane tasks that are part of maintaining and preserving a park environment contain the seeds of new interpretive strategies. On a practical level, cracks and spalls on the surface of a masonry building constitute a maintenance problem. From an exhibit viewpoint, however, the same fractures may demonstrate underlying geological settling, provide insights into the nature of rust and oxidation, or map the pattern of architectural loads impinging on a building. By recuperating processes usually thought of as deterioration or site maintenance issues into investigations, the Outdoor Exploratorium can provide visitors with new tools to see and understand a broader range of outdoor phenomena.

site fidelity

Fidelity to site has both a form and content aspect. Exhibits placed in a National Park environment, where historic preservation and site integrity are essential, are designed to blend into the existing landscape as subtle discoveries rather than become overt focal points. Vernacular forms and materials guide the design vocabulary. Exhibit content is developed out of an active engagement with site-specific phenomena rather than as preconceived illustrations of scientific concepts or new incarnations of content ideas evolved elsewhere.

project vision – encouraging proficiency

The core focus of the Outdoor Exploratorium's project vision centers on creating a learning environment that encourages visitors to develop proficiencies in skillful noticing and observation, exploration and understanding of interconnections in complex systems, and the application of scientific concepts and principles to outdoor phenomena.

noticing skills

Skill in noticing is the ability to perceive phenomena with a heightened precision and clarity that leads to deepened insight and enlarged understanding. The specific noticing skills the Outdoor Exploratorium attempted to foster are the basic components of good scientific observation:

Focusing
Concentrating attention in a systematic way.
Formulating questions to guide noticing.
Dissecting complex wholes into clearly observable parts.

Measuring
Bringing precision to observation through measurement.

Comparing and Classifying
Noticing similarities and differences in characteristics.
Grouping and organizing observations into typologies that reveal interrelationships.

Pattern Recognition
Noticing characteristic patterns that recur in a variety of forms.

Correlating and Factoring
Systematically looking for connections and causative links between different phenomena.

Hypothesizing
Using observation to prove or disprove a speculation, guess, or assumption.

Imaging, Modeling, and Mapping
Heightening observation through the making of images and models.

Archiving
Making and sequencing observational records to understand change over time.

A *noticing skill* is a proficiency more enduring than the experience of seeing or understanding something new in a one-time exhibit experience. *Skill* implies an active ability that persists in the visitor's mind independent of an exhibit or environment. The ideal outcome of a noticing skill exhibit occurs after the exhibit experience, as a propensity.

For example, as a result of using the hinged mirrors of the *Sky Mirror* exhibit to compare the luminosity of the sky from zenith to horizon, a visitor is guided through an experience of systematic attention and comparison that encourages more precise observation of sky luminosity *without* the exhibit mirrors.

complex systems

The Outdoor Exploratorium encourages visitors to investigate complexity on two levels. One approach highlights unsuspected complexity within a single phenomenon. In the *Lift* exhibit, what seems to be a simple onshore breeze is revealed to be a complex aggregate of parallel streams of air traveling at widely divergent speeds within a few feet of one another.

Another approach focuses on illuminating interconnections between multiple phenomena—physical, biological, and technological. In the *Pier Piling Pivot* exhibit, the distribution of organisms living on a waterfront pier piling is shown to be the complex product of multiple factors: pier piling architecture, fluctuating tides, seasonal changes in temperature and salinity, and a global shipping industry that continuously introduces exotic intertidal species from distant harbors all over the world.

principles and concepts of science

To provide a diversity of tools to help visitors understand and apply the principles and concepts of science to outdoor phenomena, the Outdoor Exploratorium envisioned a range of topics distributed across six content fields:

Physics
Speed of sound in outdoor environments.
Color and luminosity of the sky in relation to atmospheric density.
Optical geometry of light reflected on water.
Heat and the expansion and contraction of metals on bridge spans.
Heat and the refraction of light in mirage phenomena.

Chemistry
Oxidation and corrosion of metals in shoreline environments.

Meteorology
Vertical and horizontal stratification of onshore and offshore wind.
Regional visual history of cloud, fog, and storm patterns.

Geology
Impact of tides on the geological substrate and underground aquifer.
Seismic stress and fracture patterns on roads and buildings.

Hydrology
Wave reflection and interference patterns on the urban shoreline.
Current, tide, and seasonal water flow cycles in the San Francisco Bay estuary.
Diversity and fluctuation of salinity levels in the Bay estuary.
Water flow patterns in urban watersheds.

Biology
Gull plumage phase taxonomy; gull calls.
Effect of salinity on the distribution of estuary fish and invertebrates.
Pier piling ecology of intertidal organisms.
Pioneer plants in asphalt and concrete environments.

BRINGING SCIENCE EXHIBITS TO FORT MASON

Stephen Haller
Historian,
National Park Service

The Exploratorium's outdoor learning installations at Fort Mason perfectly realize the potential of scientific educators to collaborate with stewards of historic sites for the enjoyment of visitors to public institutions.

Fort Mason Center has brought a range of vibrant contemporary cultural uses to a historic U.S. Army transportation and logistics depot for over thirty years, while simultaneously working in partnership with the National Park Service to preserve the buildings and setting of this nationally-significant former military post. Its location in the center of San Francisco's northern waterfront also creates a singular urban/natural interface for locals and tourists alike.

Thus, Fort Mason Center and the National Park Service were delighted to be approached by the Exploratorium about adding a layer of educational installations about the physical environment to the landscape. But how to draw attention to the new features and make them as engaging as the indoor exhibits at the Exploratorium, while simultaneously respecting the design environment and historic associations of the landmark?

Sharing goals and ensuring mutual understanding of opportunities and constraints from the outset was key to all that followed. The exhibit designers' vision fit with the visitor use desires of the Fort Mason Foundation and its tenants as well as with uniform national preservation standards. A process for scoping, consultation, and review was already set up and made it easy to share information as the project developed from concept to construction. A shared desire to find new ways to engage the public with the site, combined with a flexibility based upon mutual respect, inspired and encouraged the steady evolution of our distinct ideas into a cohesive final blend.

Careful placement of the exhibits along preexisting circulation patterns, as well as their distinctly modern and technological look, draw passers-by through a seductive curiosity. The industrial style of the old Army depot is enhanced by these new features that take their surroundings—the wind, water, pier pilings, concrete, and pavement—and open our eyes to the wonder of the environment that surrounds us.

Have compatible strategic goals, communicate constantly, be flexible and creative but respectful of tradition and setting: these offer a basic but essential recipe for success for this and similar projects in the public environment.

Photos: National Park Service

the exhibits

READING THE SITE: LEARNING TO OBSERVE AT FORT MASON

Shawn Lani
Lead Exhibit Developer

As the Outdoor Exploratorium team began our work at Fort Mason, we soon realized that this urban National Park was not merely the site of an exhibition—Fort Mason *is* the exhibition. Each weatherworn pier piling, each historic wall and façade, every daily transit of the sun provided an opportunity to explore a subtle and dynamic landscape. We knew we could not easily package these phenomena as self-contained exhibits as we have done for years on the museum floor. At Fort Mason, the exhibits would need to act as framing devices—unobtrusive lenses placed carefully over existing phenomena. After years of creating objects of curiosity and wonder for Exploratorium patrons, we were now faced with a new task: interpreting a unique urban landscape for *its* visitors. Our love of exploration and fascination with Fort Mason's blend of built and natural environments deeply informed our work, and our ideas were continually fueled by discoveries and observations of particular places and particular times.

Fort Mason Center, the Golden Gate National Recreation Area, and the National Park Service provided early and continuing guidance for our evolving exhibit concepts. Our partners were as interested in our way of thinking as they were in our exhibit ideas, and their probing questions led to a deeper understanding of the site. In fact, our initial questions were what most intrigued our partners: what does it mean to use architecture as an instrument, or to think of the site as an observatory? How can we help visitors understand the implications of their observations? These questions, insightfully summarized by Project Developer Bryan Connell, guided the development of a new genre of outdoor exhibit, a wayside attraction that hones visitors' noticing skills while instilling a sense of place.

Our project goals and our partners' priorities became entwined as we navigated our new terrain. The Outdoor Exploratorium project was funded by the National Science Foundation and focused on helping visitors develop noticing skills while using scientific approaches to exploring complex phenomena. Partnering with the National Park Service and Fort Mason required that we refine our designs to remain consistent

with the site's interpretive framework of simple elegance and historical sensitivity. Adhering to both sets of constraints drove the work in new directions—avenues the Exploratorium might not otherwise have explored.

Using dyes to display land contours

Like most organizations, the Exploratorium has institutional traditions, and few run as deep as our method of iterative, experimental exhibit development. However, we knew that relying only on our tried-and-true approach would not allow us to take full advantage of this remarkable opportunity. The project and its partnerships forced us to become better observers as we searched for content embedded in the location. We tracked and tinkered, searched for meaningful and unexpected comparisons, and divided and dissected as we rigorously investigated the landscape.

But we had yet to understand how visitors might respond to exhibits placed in an open landscape. Stripped of their museum context, our exhibit installations ran the risk of seeming random intrusions, *non sequiturs* in an otherwise cohesive setting. On the other hand, pushing exhibits to become overly simplified, single-message "delivery devices" might reduce them to uninspired and static tokens. Our usual ways of informing the development process through iterative prototyping, observation, and evaluation were all curtailed due to site restrictions and the rigors of the outdoor environment. Outdoor prototypes were more difficult to engineer, even in the early stages, and nearly impossible to leave unattended overnight.

These challenges were formidable, especially considering that all of the works were designed and built in-house. Larger pieces, such as *Lift* and *Wind Arrows*, required complex fabrication strategies and the advice of structural engineers. *Speed of Sound* necessitated an auto-answer phone at the base of the Golden Gate Bridge's South Tower. Nearly every exhibit had a unique set of engineering challenges that tested the team's ingenuity and ability to find elegant solutions.

Designing an evaluation strategy that yielded useful and timely insights also called for innovation and improvisation. Focused, on-site evaluations with simple prototypes pushed early design concepts into more accessible forms. Early work on *Bridge Thermometer,* for example, stripped away multiple layers of ancillary information. After months of conceptual development, six hours of on-site evaluations sharpened both the exhibit's message and design. This development process required both evaluator and exhibit developer to understand and respect the creative and rigorous procedures of both processes.

Senior Researcher Joyce Ma outlines research and evaluation challenges elsewhere in this publication, but it's important to recognize the impact of those processes here, in the context of exhibit development. It's easy to underestimate the early undercurrents of ideas and insights that run through a multi-year project. New ways of thinking need time to ferment and diffuse themselves in ways that are difficult to quantify (or even remember) at the project's end. Our formative "noticing tours" and visitor studies along San Francisco's waterfront were important antecedents to the project's final outcome.

Broadening our exhibit development approach was a necessary adaptation, and it led to an important evolution in our approach to the creation of a sense of place based on observation and understanding. These exhibits now live at Fort Mason without us. People attending classes or having lunch, fishermen with crab nets, longtime San Franciscans and first-time visitors—all encounter these portals on natural phenomena without pretext. The installations' effectiveness can be measured by their ability to encourage a second look, to stretch a moment into a minute, to catalyze a new awareness of what seemed mundane, so that the patterns hidden within waves or winds or structures come into sharper focus. This became our driving muse: the realization that such moments can take hold and expand our awareness of both the world and ourselves.

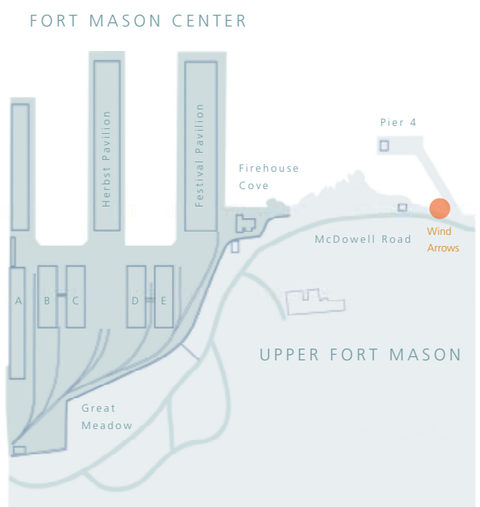
The following pages describe each of the Outdoor Exploratorium exhibits in detail. For an online tour of the collection, visit www.exploratorium.edu/outdoor.

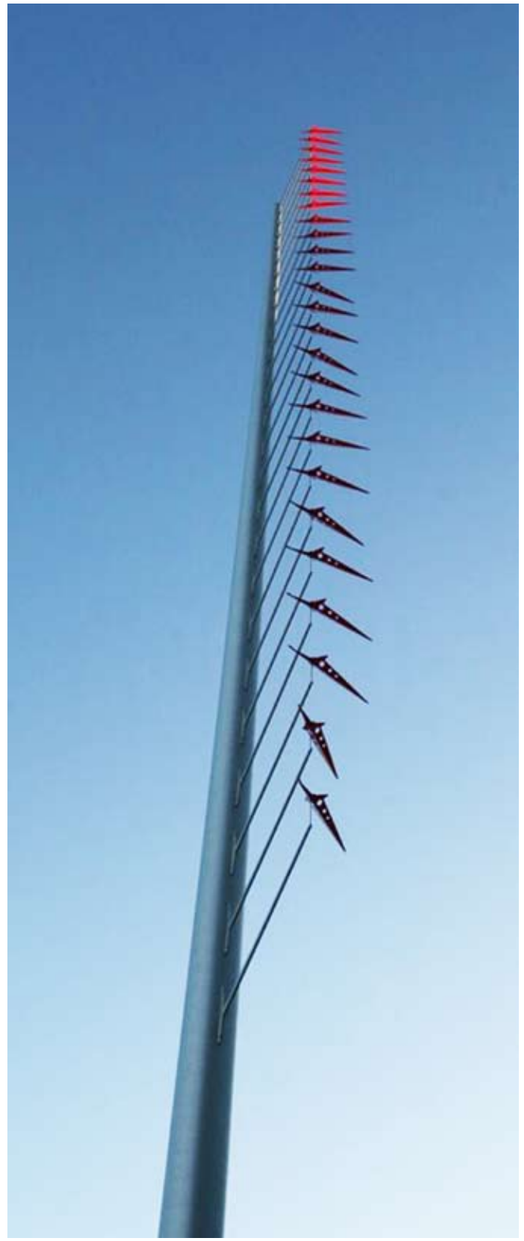
WIND ARROWS

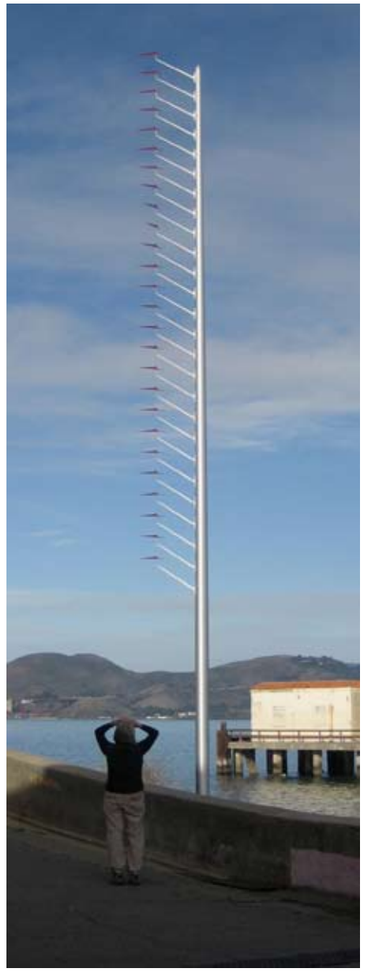
Wind shear is a measure of how wind changes direction with height. Because our bodies feel the pressure of a relatively small section of wind, we may assume that the wind flowing above us is fairly uniform in direction. In fact, wind is often highly stratified, and can be blowing at right angles to itself within 20 feet of vertical distance.

Flagpoles and sailboat mast wind indicators are common features along San Francisco's waterfront landscape. In the *Wind Arrows* exhibit, these elements are repurposed to create a way of graphing wind shear. A 35-foot flagpole is fitted with 26 angled horizontal arms attached at 1-foot intervals. A sailboat wind direction indicator is mounted at the tip of each arm. By comparing the direction of the arrow-like vanes at different heights, visitors can explore the layered complexity of wind along the shoreline.

Location: Upper Fort Mason, Aquatic Park entrance

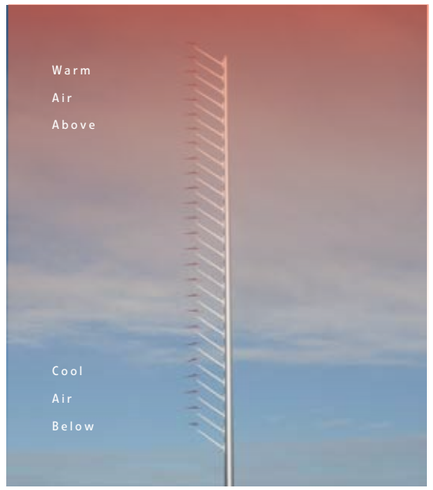




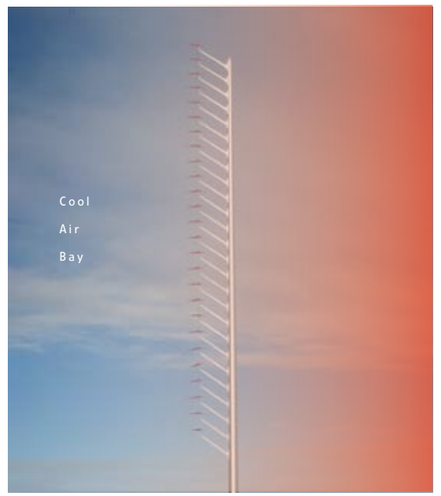


Temperature gradients and surface friction cause air to shear into layered flows with different speeds and directions. Sailboats usually have a twist built into the sail to account for wind shear.

Horizontal and vertical differences in air temperature influence the way the vanes on the *Wind Arrows* exhibit align.



Cool, heavy air close to the surface of the Bay is more resistant to directional change than the warmer, lighter air flows above. When the wind stratifies in this way, the upper and lower vanes of *Wind Arrows* twist out of alignment.



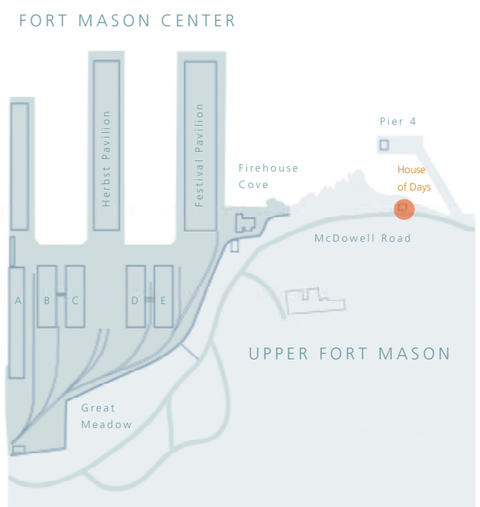
During strong, less stratified onshore winds, the vanes align in one direction as cool air from the Bay rushes shoreward to replace warm air rising from the land.

HOUSE OF DAYS

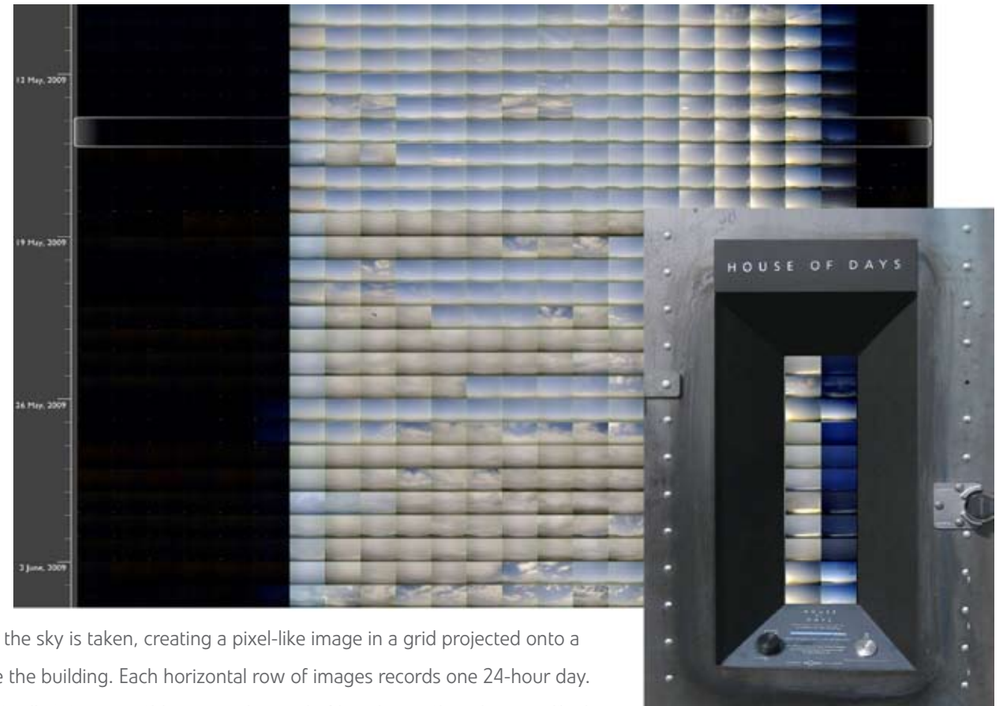
Popular media is saturated with information about weather. Satellite images of storm patterns, regional temperature maps, and detailed statistics on air pressure, humidity, and precipitation are major features of the daily news. As useful as this information is, it often takes the form of abstract numerical measurements or short term predictions that do not necessarily make us better weather observers or provide insight into long-term patterns of atmospheric change.

Located in an historic military building overlooking the San Francisco Bay, *House of Days* captures atmospheric change in the form of a purely visual sky diary. Every hour, a camera takes an image of the sky and feeds it into a quilt-like mosaic of past sky images. The resulting meteorological archive gives unique visual form to the complex long-term weather patterns that occur on time scales beyond our usual day-to-day observations.

Location: Upper Fort Mason, East McDowell Road

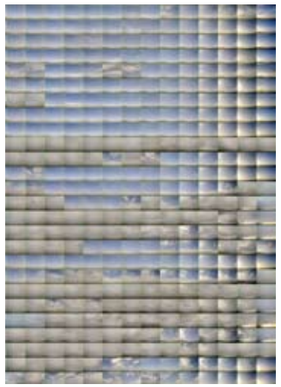


House of Days occupies a former military searchlight building built in 1911. Just as the searchlight once projected beams of light into the night sky, the exhibit projects images of the sky onto the darkened interior of the building. A viewing window and user interface inset into a steel door on the east building facade turn the structure into a interactive meteorological theater.

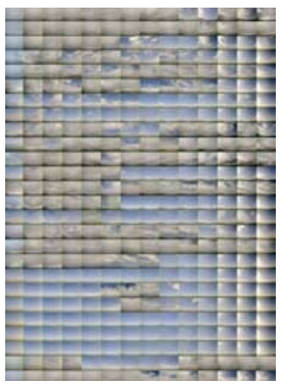


Every hour a picture of the sky is taken, creating a pixel-like image in a grid projected onto a wall-sized screen inside the building. Each horizontal row of images records one 24-hour day. Each day is stacked vertically into a monthlong visual record of hourly weather changes. Knobs at the viewing window enable visitors to scroll through different parts of the grid and enlarge individual days. A timeline at the side of the screen calibrates the images with the days and months of the calendar.

15-hr. x 26-day April sky pattern



15-hr. x 26-day May sky pattern



15-hr. x 26-day June sky pattern

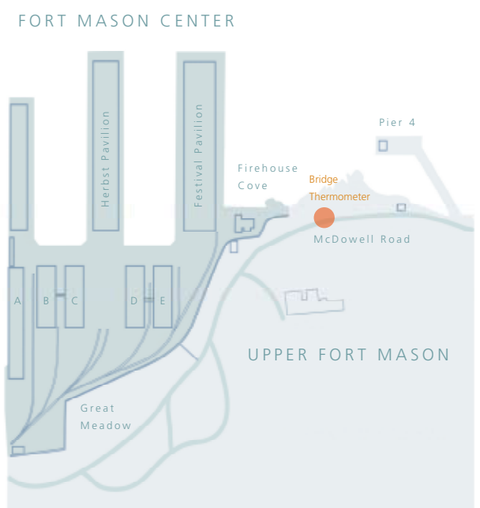
BRIDGE THERMOMETER

A San Francisco icon, the Golden Gate Bridge is a dynamic structure continuously responding to heat, moisture, traffic, and wind. Temperature alone can affect the Bridge in dramatic ways: the length of the Bridge can vary by as much as three feet from summer to winter, and the span is engineered to move up and down in a 16-foot range in response to thermal expansion and contraction of the suspension cables.

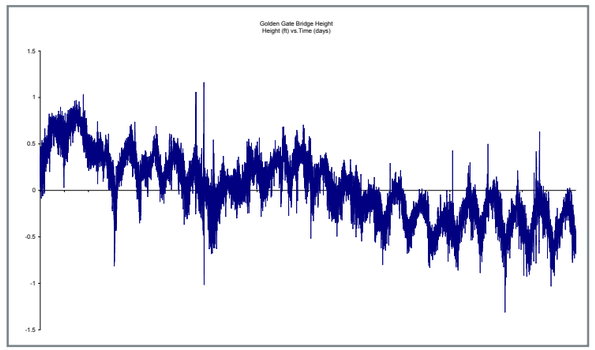
Bridge Thermometer allows visitors to view the span through a calibrated telescope that measures the height of the span as it responds to changing temperature patterns and traffic loads.

Location: Upper Fort Mason, Golden Gate Bridge overlook, McDowell Road

Photo: Galen Frysinger



The *Bridge Thermometer* viewer combines a telescope with a video camera to magnify the truss structure at the center of the span. A scale on the screen allows visitors to plot vertical movements in 1-foot increments. Although the Bridge is over two miles away, the resolution of the image is high enough to see individual cars moving along the northbound lanes.



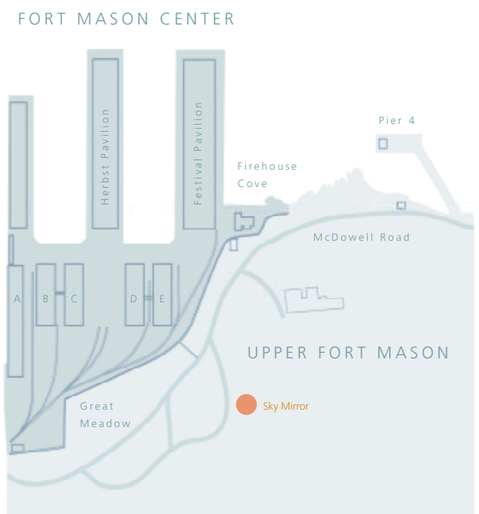
A graph of Bridge height at center span in early winter. Average height increases 1 foot in a 1-month period from November to December. Daily flucuations range from 6 to 18 inches depending on the temperature variation between night and day.

SKY MIRROR

Sky Mirror is located in the Great Meadow, an open expanse of lawn in Upper Fort Mason. The exhibit faces an unobstructed view of the western sky. A large fixed mirror reflects the color of the sky directly overhead. In the center of this mirror is a smaller hinged mirror that rotates to reflect the color and brightness of the sky at different altitudes along the meridian from horizon to zenith.

In effect, *Sky Mirror* compares atmospheric thickness. The brightness of the sky is determined by the amount of atmosphere in the line of sight—the more atmosphere, the brighter the sky. Because of the curvature of the earth relative to an observer, the atmosphere is about 38 times thicker at the horizon than overhead, resulting in a dramatic change in color and luminosity. Using the controls, a visitor can explore how the path of the sun and changing weather conditions alter the atmospheric luminosity gradient in the sky.

Location: Great Meadow, Upper Fort Mason



Located on a hillside path a short distance below *Sky Mirror*, a rotating wheel enables visitors to control the angle of reflection.

A dial synchronized with the exhibit mirror correlates the observed color and luminosity of the sky with the thickness of the atmosphere.

On a clear day, the sky is fairly uniform in color from the zenith to about 40° above the horizon.

At 40° meridian, increased atmospheric density caused by earth's curvature scatters more light.

Matching levels of highly scattered light on the east and west horizons creates a window-like effect.

F L O W P O I N T S

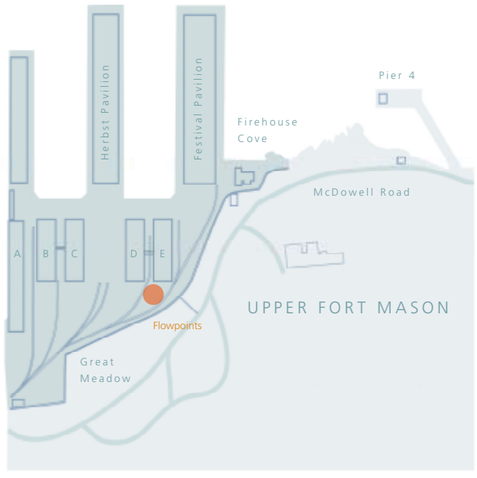
The architectural density and vast network of streets, sidewalks, and parking lots in urban environments have a strong impact on the hydrological cycle. Water that would normally infiltrate into underground aquifers or be utilized by plant and animal life is channeled and transported to distant locations through highly-engineered watersheds. A host of environmental issues often ensues.

Flowpoints encourages visitors to become more detailed observers and explorers of urban watersheds by experiencing the subtle topography, hydrology, and botany of a parking lot environment at the east end of Fort Mason Center.

In a seemingly flat and lifeless lot, close examination reveals a surprisingly contoured landscape with water flow patterns marked by oxidizing pavement minerals and highly adaptable pioneer plants.

Location: Landmark Building E parking island, Fort Mason Center

FORT MASON CENTER



Flowpoints uses survey benchmarks to mark elevation changes in the surrounding landscape. Icons on the exhibit graphic cylinder provide a benchmark recognition key.

A biological survey marker highlights a pavement fracture occupied by Knotweed (*Polygonum arenastrum*). Pioneer plants colonizing the urban street environment can be found by following rust streaks on the pavement. The rust streaks are caused by iron ore concentrations in the aggregate used to make paving asphalt. The length, width, and direction of the streaks outline slope contours and paths of water flow.

A montage illustrating symbols used to distinguish the ridge, valley, drain, and biological survey markers. Street level view of the Building E parking island shows the exhibit cylinder location.

NORTH

WEST

EAST

SOUTH

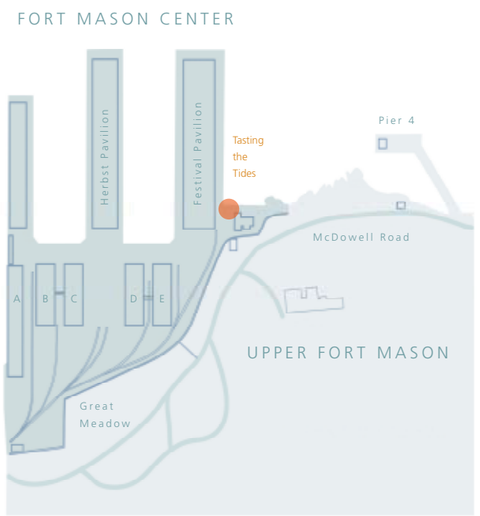
An overhead map of the Landmark Building E parking lot reveals a subtle urban watershed of ridges, valleys, and basins. Elevation differences between the surface of the parking island and the lowest drain points can exceed two feet. Abandoned railway lines function as seasonal streambeds.

TASTING THE TIDES

Salinity plays a critical role in both the human body and the San Francisco Bay estuary. Without the dissolved salts in our body fluids, our nerves could not conduct the electrochemical impulses basic to our lives. In the estuary, salinity levels fluctuate dramatically with tides, currents, location, and season, playing a key role in defining the range and habitat of countless freshwater and marine organisms.

Using a special low-flow drinking fountain, *Tasting the Tides* allows visitors to taste a varied range of salt concentrations typical of water flowing from the Delta through the Bay estuary into the Pacific Ocean.

Location: Lower Fort Mason, Firehouse Plaza



Tasting half as salty as the sea, a 1.7% salinity level is optimal for Pacific Herring to spawn. Adult Herring live in the ocean but use San Francisco Bay as a nursery for their young when winter runoff dilutes the saltiness of the water for several months in spring.

Photo: Gina Sanfilippo

Distinctly salty to human taste, the 3.5% salinity level of the Pacific Ocean is the norm for Great White Sharks. Water at lower levels of salinity can be stressful for Greta Whites, one of the reasons they are seldom seen in the San Francisco Bay.

Visitors can meter the percentage of salt in the water they drink from *Tasting the Tides*. In this way, they can explore a range of salinities that different organisms in the San Francisco Bay are adapted to.

Photo: Marcio Cabral de Moura

Perceived as slightly salty, 0.9% is the level of salinity in the blood, sweat, and tears in the human body. A person swimming in the Sacramento River before it empties into San Francisco Bay is nine times saltier than the surrounding fresh water.

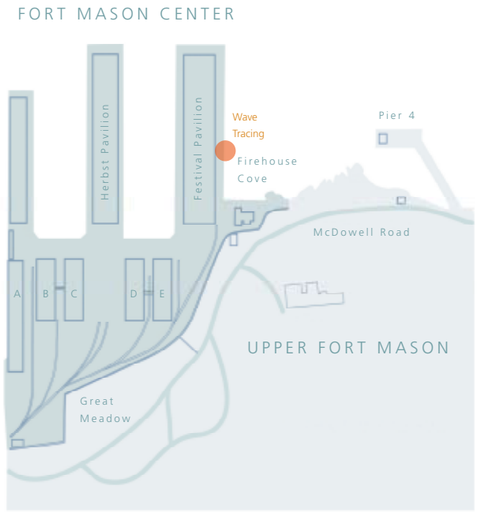
Like many invertebrates in the Bay, the Native Olympic Oyster functions best at a moderate 2.5% salinity level. Once abundant, declining Olympic Oyster populations are slowly becoming re-established.

WAVE TRACING

Originally designed to cushion large cargo ships during docking, many of the fender pilings lining the pier aprons at Fort Mason have loosened with time. Detached from their moorings, the pilings now sway and oscillate in response to waves, tides, and currents.

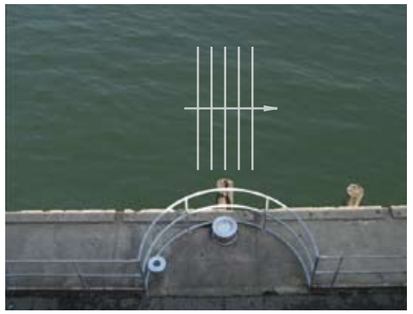
Wave Tracing uses one of these aging structures as a kind of "accidental instrument" to track the size and direction of the waves in the Firehouse Cove region of Fort Mason Center. An attached metal stylus translates piling motions into tracings that can be seen inside an enclosed, glass-covered sand tray. Varying in sensitivity with the height of the tide, the stylus draws a shifting array of lines, loops, and circles that reflect the often intricate wave interference patterns that occur in the Cove.

Location: Lower Fort Mason, Festival Pavilion East Pier Apron facing Firehouse Cove

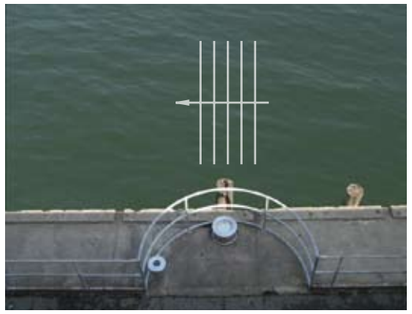


By observing *Wave Tracing* sand patterns, visitors can discern four major wave types at work along the pier apron of Firehouse Cove: boat wakes, deflected wind waves, seawall reflections, and waves reflected from the rocky shoreline of Black Point.

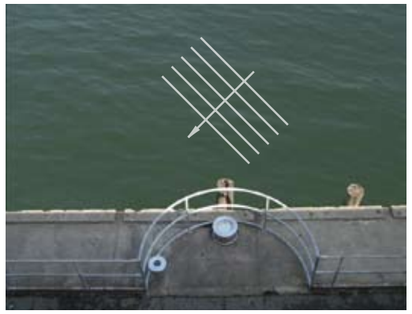
Boat and ship wakes are about 20° off the bow, traveling to the pier from the northeast.



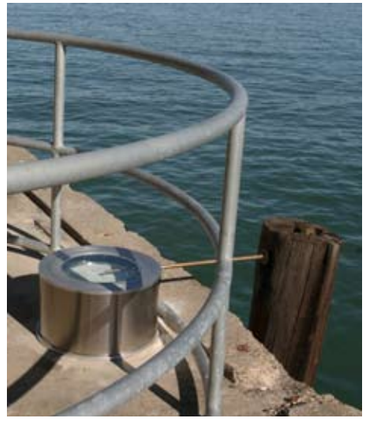
Northwest wind waves deflect off the end of Festival Pier, moving shoreward.



Reflected waves bounce off the Firehouse Cove seawall, travelling back out to the Bay.



Waves reflecting off the Black Point rocks come from the southeast at an angle of 45°.



Orientation to *Wave Tracing* is provided by a cylindrical information well positioned at one end of the exhibit observation deck. Looking into the window of the well, visitors can see a sequence of digital images illustrating common wave patterns.

PIER PILING PIVOT

Seen from a distance, the organisms that live on the fender pilings lining the piers of Fort Mason Center don't seem to have the appeal we associate with the colorful sea stars, urchins, and hermit crabs inhabiting the rocky tidepools of the Pacific coast.

On closer examination, intertidal life on the pilings is surprisingly diverse and tells an equally compelling story. Inhabited by a mix of native species and exotic, bio-invasive organisms that arrived on the hulls or in the ballast of marine transport, the pilings are a window into the Bay's shifting ecological dynamic in an era of global shipping and world trade.

Pier Piling Pivot rotates a fender piling out of the water so visitors standing on the shoreline can examine it. A graphic legend identifies the intertidal zones on the piling and the plant and animal life occupying this unique environment.

Location: Fort Mason Center, Festival Pavilion

FORT MASON CENTER

Pier Piling Pivot lifts a normally inaccessible intertidal environment so that visitors can explore pier piling biology in detail.

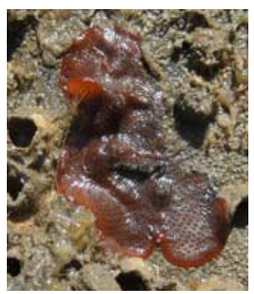
White Acorn Barnacles flourish in the high intertidal zone.

Pushing a rail-mounted button raises the piling. When raised, the lower end of the piling aligns with a set of rotating graphic prisms that identify the common plants and animals of the intertidal zone.

Photo: Peter J. Bryant, UC Irvine

Sea Nymph Worms forage in the middle intertidal region.

Star and Chain Tunicates also thrive on ship hulls.



Lacy Bryozoans are an exotic species from Japan.

Photo: Peter J. Bryant, UC Irvine

Skeleton Shrimp are found in the low intertidal region.

Juvenile Brown Rock Crabs mature on piling substrates.

RUST WEDGE

A major issue in the preservation of historically significant waterfront buildings, *spalling* occurs when water enters cracks on the surface of a masonry structure and oxidizes the underlying steel reinforcing material. Since oxidizing iron increases in volume as it decays, the result is an internal wedging action that forces chunks of concrete from the building surface in irregular patches. Spalls map the areas where the greatest architectural stress is occurring due to dead loads or seismic settling. Stress-weakened surfaces eventually develop cracks, allowing the rusting process to begin.

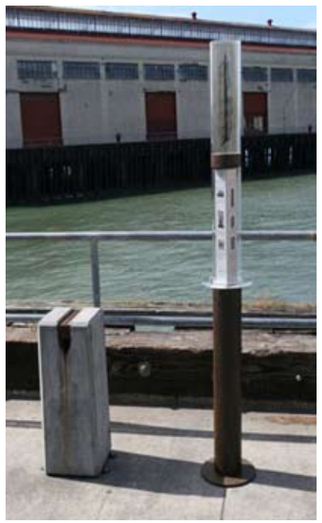
Rust Wedge illustrates the power of the spalling process by placing a stack of iron plates in the cleft of a specially-designed block of concrete. Exposed to rain, dew, and fog, the rusting plates expand, slowly fracturing the block over time.

Location: Lower Fort Mason seawall adjacent to the Festival Pavilion

Steel plates placed inside the cleft of this concrete block can expand 2 to 4 times in volume during the rusting process, forcing the block apart.

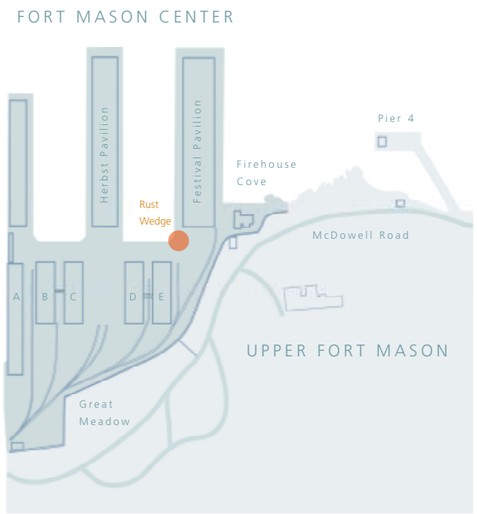
Spalls are more likely where the weight of beams over openings stresses the centers of spans.

Spalls follow small fractures created by surface joints and architectural details.



Directly across from the *Rust Wedge* exhibit, the east wall of the Herbst Pavilion pier shed contains many examples of spalling.

Spalls are often the result of stress risers that develop at the sharp corners of doors and windows.

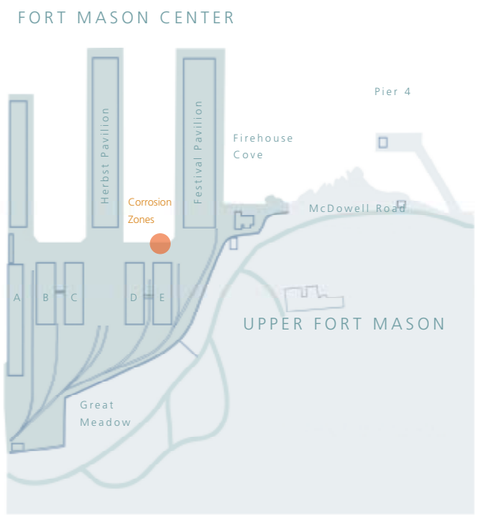


CORROSION ZONES

Like many marine industrial environments, the pier pilings along the seawall at Fort Mason Center are host to an assortment of metal ladders, chains, and hoists. Products of a bygone era, these structures have rusted and deteriorated over time. Careful examination of these objects yields insight into the nature of the invisible electrochemical zones that govern corrosion rates along the shoreline.

At *Corrosion Zones*, visitors compare corroded chains of different ages to see how metal reacts to the varied mixtures of salt, air, and water created by changing tidal conditions. The results can be surprising. Corrosion rates are mild underwater compared to the harsh Splash Zone, yet in the neighboring Intertidal Zone the rusting links of a steel chain can actually double in size rather than deteriorate.

Location: Fort Mason Center pier slip between Herbst and Festival Pavilions



Small rusty surface pits characterize chain exposed to the Atmospheric Corrosion Zone.

Chain links with cracked, flaking surfaces are found in the highly corrosive Splash Zone.

In the Intertidal Corrosion Zone, alternating cycles of air and salt water can cause rusting chain links to double in diameter.

A light post along the edge of the Festival Pavilion pier slip serves as the armature for *Corrosion Zones*. On one side of the post, visitors can examine the links of a rusted steel chain that once hung from a pier piling below the light post. A new chain of the same size is provided for comparison.

A chain of copper spheres hangs parallel to the two steel chains. Copper oxidizes differently than steel in a marine environment, producing marked color changes according to variations in corrosive intensity.

Prior to display, the copper exhibit chain was exposed to typical tide and weather conditions along the Fort Mason seawall. The spheres turned brown, orange, red, and green according to their position in the corrosion gradient.

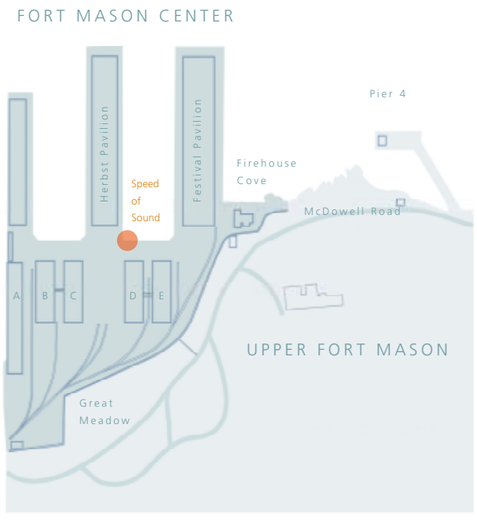
Corrosion is mildest in the center of the Intertidal Zone, and harshest at the turbulent edges of the upper and lower tidal regions. In the Atmospheric and Submerged Zones, copper produces patinas that resist further oxidation.

SPEED OF SOUND

The fact that light travels faster than sound seems obvious and unremarkable, yet we seldom realize how much of a lag there is between what we see and what we hear in an outdoor environment.

Speed of Sound uses nautical signaling devices to explore how our perception of light and sound changes with distance and temperature. On a small scale, visitors can compare the time it takes a bell tone and a light to reach them from a pier 700 feet away. From the same vantage point, a bell 1 1/2 miles away can be seen and heard—but only if the air temperature gradients on the surface of the Bay are within certain ranges. On days when it's foggy at the Golden Gate Bridge, visitors can use their cell phones to time the difference between when a foghorn actually sounds and when they hear it. At Fort Mason (two miles away), the sound of a Bridge foghorn is usually at least 9 seconds old.

Location: Lower Fort Mason, seawall between Herbst and Festival Pavilions



A button on the side of the exhibit column simultaneously activates a bell and light 700 feet away at the end of the Festival Pavilion pier. At this relatively short distance, the bell is heard 1/2 second after the light.

Speed of Sound light bell

Alcatraz bell buoy

By sighting slightly left of the *Speed of Sound* light bell, the Alcatraz bell buoy can be seen further out in the Bay. At a distance of 1 1/2 miles, the Alcatraz bell tone takes 6 1/2 seconds to reach Fort Mason. Temperature differences in the layers of air close to the water can bend sound waves up or down, making the bell loud or imperceptible from the shore.

Photo: Bob Stoffberg

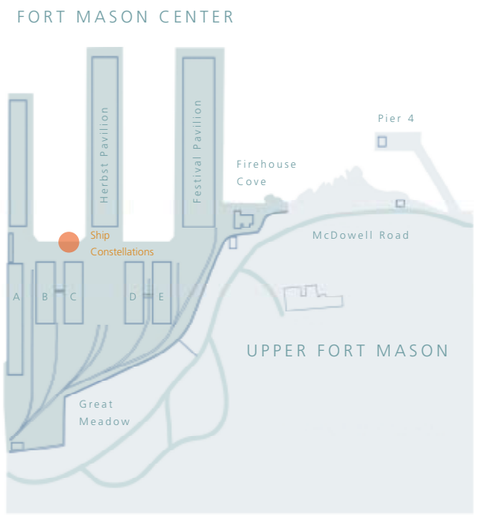
The south tower of the Golden Gate Bridge has a powerful foghorn driven by compressed air. A sensor attached to the foghorn connects to a live phone link, allowing listeners in San Francisco to use their cell phones to measure how long it takes the sound of the foghorn to reach them.

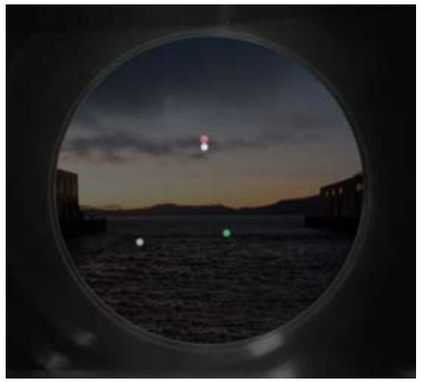
SHIP CONSTELLATIONS

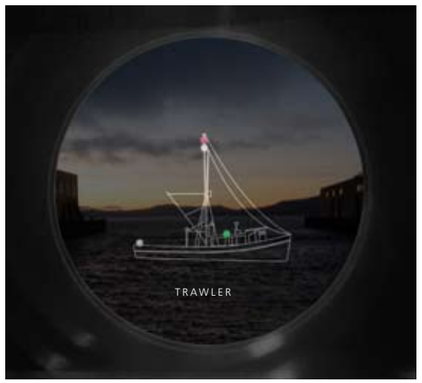
Most of the outdoor field sciences—botany, zoology, geology, meterology, and astronomy—begin with descriptive taxonomies. Classifying, ordering, and identifying phenomena in a precise way hone the systematic observation and noticing skills required for deeper insight and understanding.

Ship Constellations encourages visitors to apply the comparative observation skills associated with natural history activities like birding or plant identification to the "unnatural history" of a marine technological environment. The exhibit identifies the common patterns of navigation lights used by different types of vessels that sail the Bay at night. Star-like in appearance, these running light "constellations" enable mariners to safely navigate urban ship traffic, just as true stars provided a reliable orientation framework at sea for earlier generations of sailors.

Location: Lower Fort Mason seawall next to Herbst Pavilion



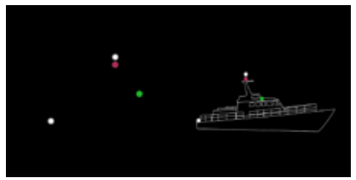


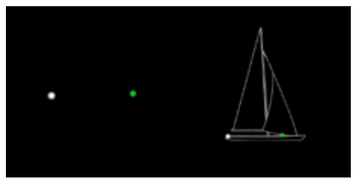


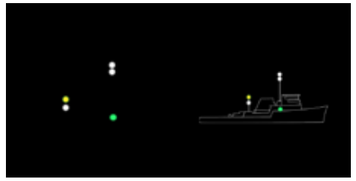
Inside the viewer, navigation light patterns are followed by an image of the corresponding boat or ship. Seven types of vessels commonly seen on the San Francisco Bay are presented.

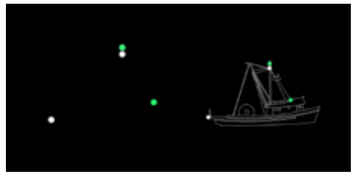
During daylight or evening, visitors look through the *Ship Constellations* viewer onto the slip between Pier 1 and the Herbst Pavilion pier. An angled, half-silvered mirror inside the viewer superimposes images of marine craft and navigation light patterns onto the scene, making the vessels appear as if they are floating to scale in the water of the slip.

Ship Constellations is located near the Herbst Theater.









Navigation light patterns for a pilot boat, sailboat, tug, and trawler.

PORTABLE OBSERVATORIES

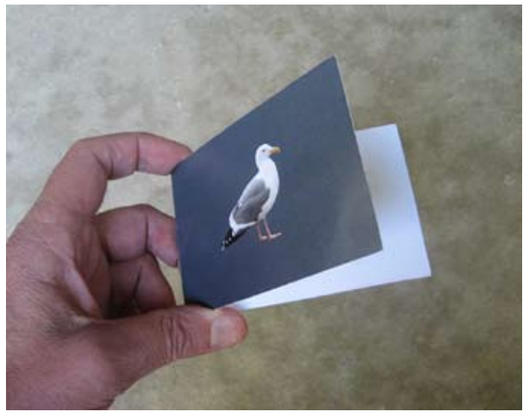
In times past, visitors to the San Francisco shoreline at popular locations like the Cliff House or Sutro Baths might purchase an "exhibit card" from a mechanical vending machine. Designed as souvenir keepsakes, these cards celebrated pop culture icons like movie stars or sports heroes and had little to do with the place where they were distributed.

What would an "exhibit card" look like in an Outdoor Exploratorium context? *Portable Observatories* is a free outdoor vending machine that produces cards that vistors can carry with them to become better observers of the natural phenomena at Fort Mason.

The current *Portable Observatories* card illustrates the four distinct plumage phases that Western Gulls move through as they grow, giving visitors a sense of the approximate age of the birds they see.

Location: Lower Fort Mason, Pier 1 seawall

Folded cards that function as site specific field guides are available at the *Portable Observatories* dispenser.

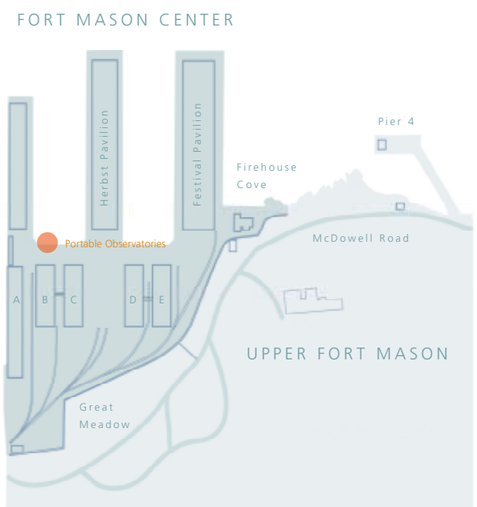


The Western Gull exhibit card unfolds to illustrate four plumage phases. First and second winter juveniles progress from dark, dusky plumage to a lighter, more mottled appearance. By the third winter, grey scapular and black and white primary feathers appear. The plumage of a mature breeding adult emerges after 4 years.

Pop culture predessors: mechanically dispensed 'exhibit cards" were popular at tourist attractions as site mementos.

Photo: Travis Nep Smith

Gulls of many ages are found at Fort Mason due to the close proximity of Alcatraz Island, a Western Gull breeding and nesting site. Western Gulls frequently roost on the ridgelines of the Fort Mason pier sheds.



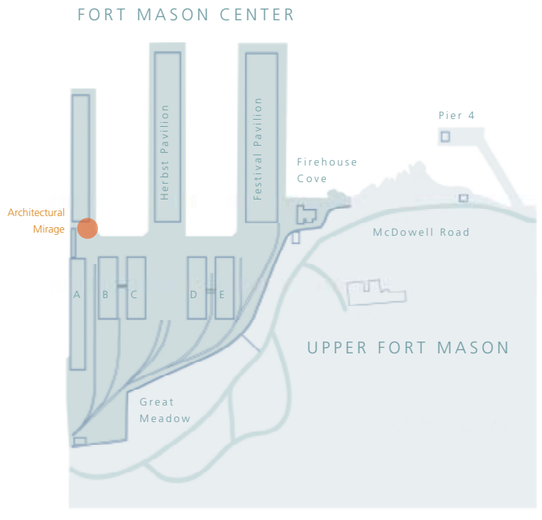
ARCHITECTURAL MIRAGE

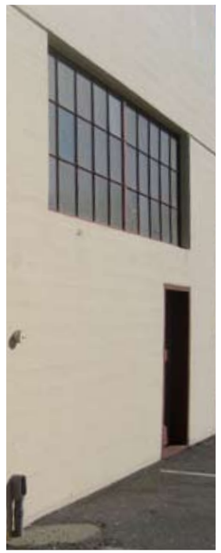
In a museum setting, architecture *houses* exhibits, functioning as a neutral container for the exhibit content within. What happens when the building itself is the object of inquiry and display?

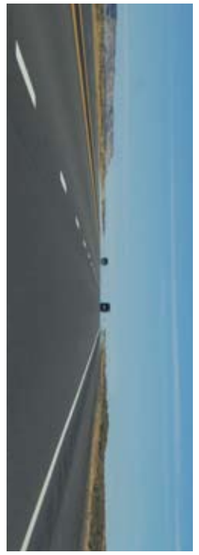
Architectural Mirage uses the south-facing wall of a Fort Mason pier building to investigate the way heat radiating from architectural surfaces refracts light, creating the visual distortions we call mirages.

A large doorway on the front of Pier 1 provides a inset walkway that allows visitors to use the masonry wall to the east of the doorway as a "thermal lens" to sight architectural features on nearby buildings. Differences in temperature between the heated air close to the wall and the cooler surrounding air create shimmering mirages like those seen on roads, deserts, and ocean horizons.

Location: Fort Mason Center, Pier 1

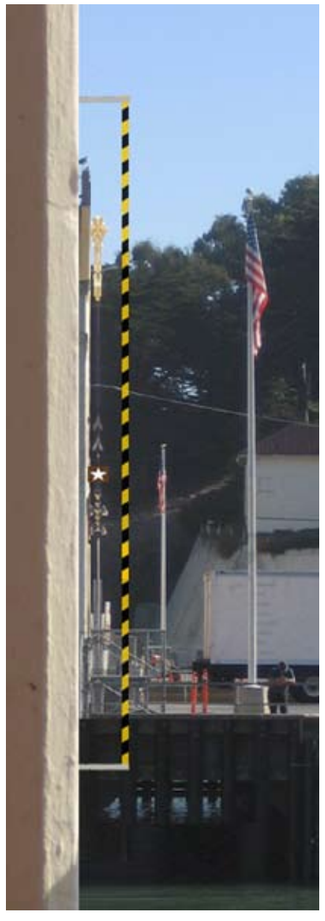






When heated, the vertical wall of a building can produce *inferior* mirages similar to those seen on the horizontal surfaces of highways.

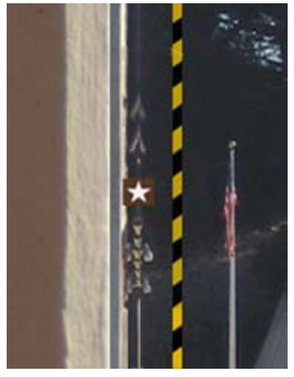
With the aid of graphic panels, alignment marks, and a wall thermometer, visitors at the *Architectural Mirage* exhibit can use the south wall of Pier 1 to explore vertical building mirages.



A sighting device mounted at the east end of the Pier 1 wall frames the mirror-like optical distortions that can be seen on the south facade of the Herbst Pavilion several hundred feet away.

The most prominent architectural ornament on the front facade of the Herbst Pier Pavilion is the U.S. Army Quartermaster symbol. Seen here in front view, the symbol can also be seen in profile from the exhibit.

Viewed in profile and sighted through the heated layers of air at the Pier 1 wall, the Quartermaster symbol appears as a narrow molding that seems to float off the surface of the building as a detached symmetrical emblem.



A half-star graphic mounted on one of the windows of the Herbst Pavilion appears to be a whole star when sighted in the viewing frame of the exhibit.

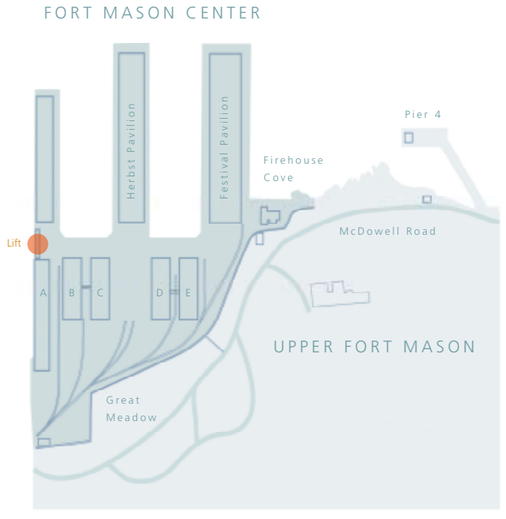
L I F T

Drawing on the aerodynamics of bird flight and the rigging technology used in sailboat design, *Lift* is comprised of sets of wing-like airfoils that move up and down vertical cables. Spaced at equal intervals along a horizontal support line, the vertical cables resemble the strings of a harp suspended across an opening between two buildings.

The airfoils on the cables rise and fall according to wind speed. The result is a kind of "aerograph," a device that graphs how the speed of the wind changes across a horizontal distance.

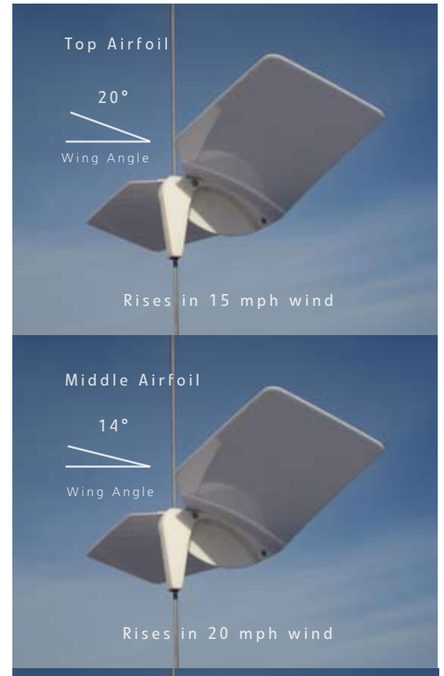
Normally invisible to the human eye, the subtle streams of moving air within a larger flow of wind can be surprisingly diverse in number, size, speed, and location.

Location: Lower Fort Mason between Building A and Pier 1



Lift graphs differences in the speed of the wind at 2-foot intervals for 100 feet along a horizontal transect between two buildings. Rarely unified, wind usually diversifies into many distinct flows that can vary dramatically in speed within a few feet.

The smooth motion of a gull in flight disguises the complexity of the wing adjustments necessary to navigate subtle variations in wind speed.



Each of the vertical cables on the *Lift* exhibit has a set of 3 airfoils that slide up and down. On calm days, the airfoils are stacked together at the base of the cables. The top, middle, and bottom airfoils each have different wing angles, so they lift at different wind speeds. The speed of the wind at each cable can be estimated by counting how many airfoils have risen.

FRACTURE MAPPING

The formal study of the joints, fractures, and faults that occur in natural rock formations is long established in geology. But what about the "artificial geology" of asphalt and concrete—the rock-like geography of urban environments? What insights are revealed when these engineered materials are seen through the lens of geological observation?

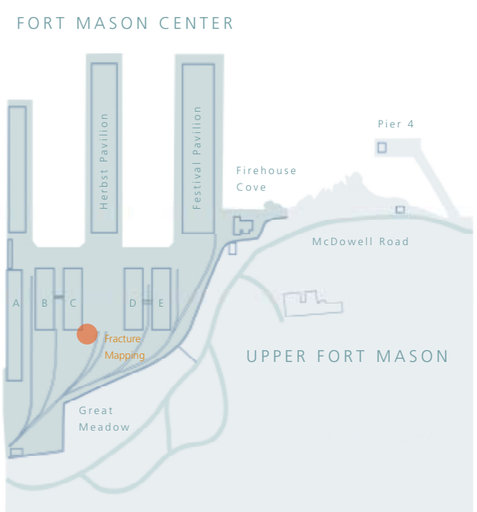
Fracture Mapping encourages visitors to be informal investigators of the fracture patterns that have formed on the asphalt paving of the Fort Mason Center parking lot. By following symbols embedded in the pavement, visitors can identify the major types of fracture geometries and the physical, geological, and technological forces that cause them.

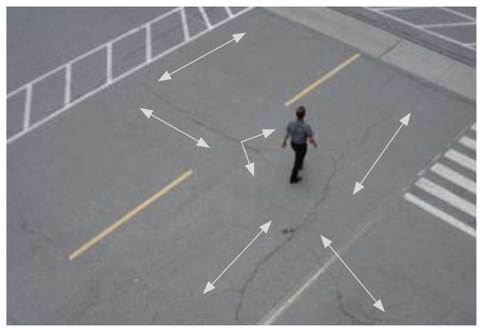
Location: Fort Mason Center, main parking lot adjacent to Landmark Building C

An exhibit graphics column displays aluminum icons that match identical symbols embedded in the pavement of the parking lot. Visitors use the column as a key to identify the different fracture systems they see.

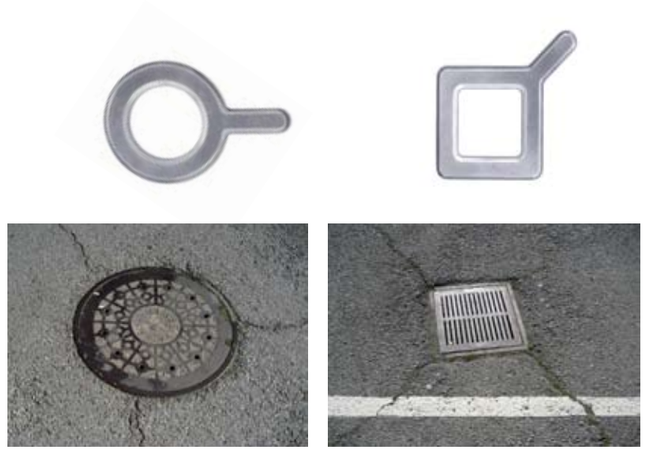
Fractures parallel to the roadway are usually caused by the weight of vehicles. Fractures perpendicular to the roadway are usually of geologic orgin. On paved surfaces, stress lines from both sources frequently meet at 90° angles in T -shaped intersections.

When a surface is evenly stressed in all directions, the most efficient way for it to break is in a Y-shaped fork composed of three 120° angles. This pattern, called *triple junction*, is found in many natural phenomena, from honeycombs to cloverleafs.





The fractures on the surface of a parking lot are a portrait of intersecting loads and forces. The weight of vehicles and architecture, underground water flows, differential heating and cooling, geological settling, and periodic seismic movements all play a role.



Geometric shapes cut into the pavement create fractures called *stress risers* that radiate from circular edges and sharply-angled corners.

Stress patterns in pavement mirror the fracture mechanics in other technological structures, During WW II, early Liberty Ships suffered serious hull damage due to stress risers that arose from the sharp corners of rectangular deck holds.

AUDIO FIELD GUIDES

Of unquestioned practical value, parking lots are not sites we usually associate with developing noticing skills or enriching scientific understanding of the environment. They are often seen as a kind of utilitarian desert—necessary, but bleak and uninteresting.

Can parking environments be places that enable visitors to become better observers and interpreters of the world around them? *Audio Field Guides* explore this question by interpreting parking spaces as miniature auditoriums where vistors can explore the sonic environment of Fort Mason on their car radios.

By listening to brief recordings, visitors can learn to decode ambient shoreline sounds like foghorns or gull calls into more precise understandings that prompt further observation and investigation. The easily programmable nature of radio broadcasts makes a wide variety of topics possible.

Location: Lower Fort Mason, main parking lot

Signs at the main entry gate display the FM radio frequency visitors can use to tune their car radios to the *Audio Field Guides*. Additional signage modeled on the entry gate design is interspersed at different points in the parking lot.

The tone of a foghorn is unmistakable, but many visitors are unaware of the signal code that links the unique pitches and intervals of different San Francisco Bay foghorns to the geographic features they represent. The *Fog Signal Audio Guide* identifies the signal pattern and location of the foghorns most commonly heard at Fort Mason.

Photo: Camden Hackworth

Gulls have a distinctive social language that usually goes unnoticed by humans. The *Gull Call Audio Guide* enables visitors to distinguish between the food, alarm, and mating calls of the Western Gull.

UNDERGROUND ESTUARY

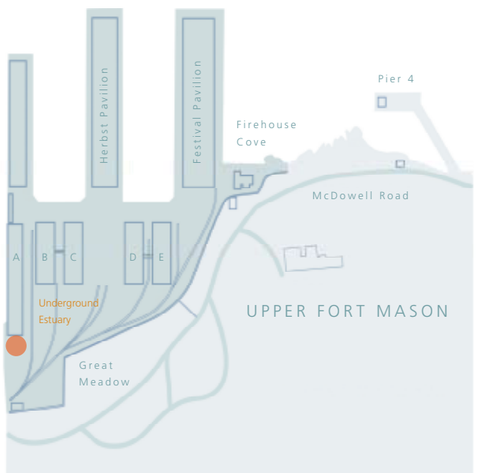
Most of the phases of the earths' water cycle are highly visible—oceans, clouds, rain and snow, lakes, rivers, and streams. Yet 97% of the worlds usable freshwater comes from an invisible source—the vast aquifers that lie beneath the surface of the earth.

Underground Estuary gives visitors a window into the dynamics of underground water flow at the shifting boundary between fresh and saltwater aquifers. Linked to a monitoring well, the exhibit tracks the influence of San Francisco Bay tides on the groundwater beneath Fort Mason Center.

Geological substrate, seasonal rainfall, ocean tides, freshwater tributaries, and geographic proximity to the shore all govern constantly-changing salinity levels in the underground estuary that permeates the landforms on the margins of the Bay.

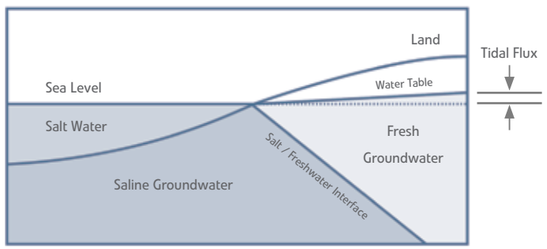
Location: Entry Plaza, Building A, Fort Mason Center

FORT MASON CENTER



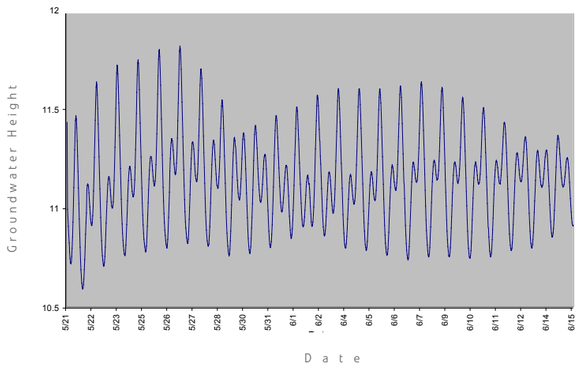
The entry plaza at Fort Mason Center offers an unexpexcted window into the invisble geological estuary below.

A water column visible in the reservoir of the *Underground Estuary* exhibit connects to a 25-foot deep monitoring well directly below. Responding to fluctuations in the height of the subsurface water table, the level of the water column can vary as much as 15 inches between high high and low low tides.



The greater density of salt water exerts hydrostatic pressure on fresh groundwater along a sloping underground gradient. Tidal flux adds dynamic pressure cycles.

A float in the exhibit reservoir translates changes in water level to a chart recorder above. The rotating drum records one month of water table data.



One-month plot of daily groundwater height shows the unequal diurnal phases characteristic of a mixed semidiurnal tide cycle.

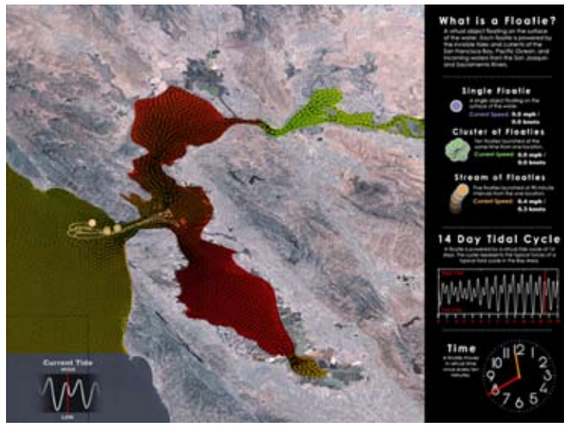
BAY MODEL

Designed to link the Exploratorium to the outdoor exhibits at Fort Mason, the *Bay Model* allows visitors to interact with a scientifically accurate virtual model of how tides, currents, and rivers combine to create the complex water flows of the San Francisco Bay estuary.

Using a touchscreen, visitors place virtual floats into a video image projected onto a three-dimensional geographic model of the Bay Area. After a float is launched, visitors watch how currents move the float to different locations according to predicted tide and river flow cycles.

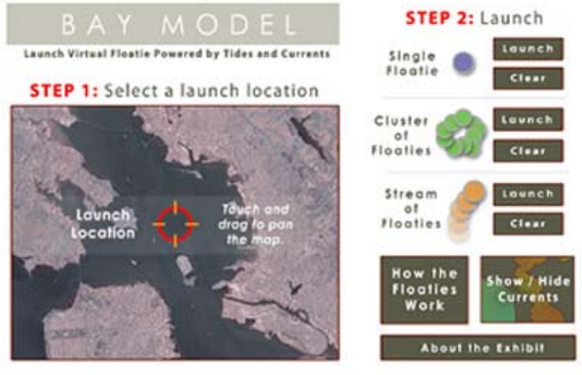
Placed next to an Outdoor Exploratorium slideshow, the *Bay Model* provides context for Fort Mason exhibits that investigate salinity levels (*Tasting the Tides*), wave and current patterns (*Wave Tracing*), and the distribution of intertidal organisms (*Pier Piling Pivot*).

Location: Exploratorium



Color coding highlights varied water conditions during tidal phases.

An overhead video projection lets visitors explore the fluid dynamics of the San Francisco Bay in aerial perspective. As an estuary oscillating between freshwater influx from the Delta and marine influences from the Pacific Ocean, San Francisco Bay has more cyclical variation in temperature, salinity, turbity, and biological compostion than a true marine bay.



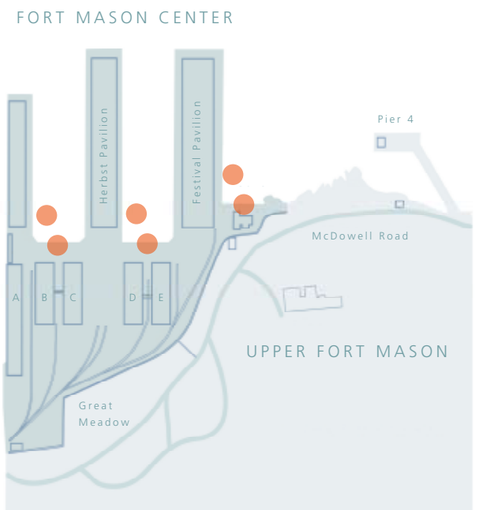
A touchscreen interface orients visitors. Visitors can launch a single float and watch how it reacts to currents, or observe more complex patterns using clusters of multiple floats.

SKY, WATER, LIGHT

The rapidly-emerging world of mobile phone applications offers many opportunities to create observation-enhancing tools for exploring and understanding outdoor phenomena.

Sky, Water, Light is an iPhone application developed to help visitors investigate water reflection phenomena along the shoreline. The Fort Mason finger piers create long, narrow strips of relatively calm water that make good optical laboratories for studying reflection gradients. Visitors can download the application and use it to photograph, sample, and compare variations in water color along a vertical transect from horizon to shore. An interactive ray-tracing diagram heightens observation by demonstrating the angular symmetry between incident light from the sky and reflected light seen on the surface of the water.

Location: Pier slips, Firehouse Cove, Fort Mason Center



Icons link to the four main functions of the application:

The Capture function enables users to photograph water reflections and perform interactive color sampling.

The Compare function stores water reflection images taken in varied weather conditions for comparative examination.

The Inquire section provides a brief orientation to the scientific principles involved: the reflection, refraction, and scattering of light in water and the atmosphere.

The Settings section turns on or off a tutorial that provides step-by-step guidance on using the application.

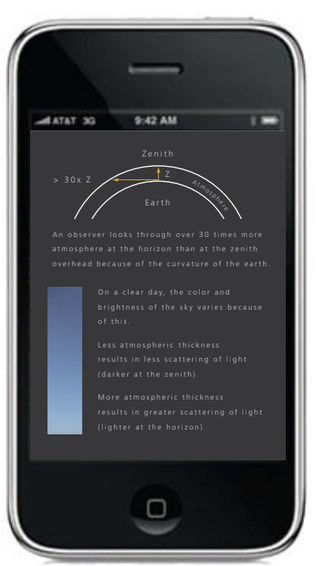
A vignetting mask helps align the iPhone camera to the water horizon.

Once a photo is taken, a transect of movable color sampling points appears.

Movable samples enable color comparisons between near and distant water.

An interactive diagram illustrates optical geometry of incident and reflected light.

Photo libraries allow users to compare reflections under varying conditions.



Content panels provide basic orientation to the scientific principles involved.

Brian Connell
Project Developer

Graphic signage plays a key role in showing visitors how to use and derive meaning from exhibits. In a National Historic District like Fort Mason, it is essential that project signage be compatible with the ambience of the site—it must be noticeable and attractive, but in subtle ways that do not add visual clutter or interfere with public appreciation of existing natural and historical resources.

One of the goals of the Outdoor Exploratorium is to provide a stimulating public learning environment without over-defining the landscape with an excess of well-intentioned "educational graffiti." Fort Mason Center hosts a diverse and constantly changing mix of public events, and a large number of the visitors are there for reasons other than the Outdoor Exploratorium. For these audiences, the Exploratorium exhibits are truly waysides—small, unexpected detours and discoveries they find on the way to something else. This offers a rich opportunity and a challenge: how does the Outdoor Exploratorium exhibit graphic strategy accommodate this paradoxical need to be both subtle background and alluring foreground?

reduced footprint

One approach to this challenge is to reduce the large graphic footprint often associated with flat outdoor interpretive panels. A graphic can be reduced by two-thirds by wrapping it around a three-sided, rotating prism. By enclosing a rotating prism in a clear acrylic cylinder and mounting it on a narrow column, a interactive graphic object can be made that attracts curiosity, yet blends with the many other vertical, pipe-like forms in the marine industrial landscape of Fort Mason. Adding an iconic object or image above the prism attracts attention without introducing large text or logos.

multiple planes of content

Putting information on a rotating prism divides content into smaller, easy-to-absorb units and gives visitors control over how much they read. For the casual visitor, a single information panel may suffice. Others with more interest can rotate the prism for more planes of information.

enclosed players

The Outdoor Exploratorium developed several devices that play loops of digital slides in an outdoor environment. This allows complex information to be reduced in size and displayed in sequence instead of being displayed all at once in a large, highly visible or information-dense graphic panel.

pictorial narratives

Another approach to reducing information density while improving content accessibility is to format graphics as *picture caption narratives*: core concepts are presented in image form with a brief caption of no more than three or four sentences. An alternating rhythm of brief text and image works particularly well on the narrow columns of a graphic prism. In informal outdoor learning environments, visitor interest is highly variable, weather is a factor, and many stimuli are competing for attention. Breaking exhibit information into easily absorbable units respects the limits on attention visitors may initially have in complex outdoor settings. Highly pictorial narratives can also be more intelligible to non-English-speaking visitors.

proximity design

To blend more effectively with the historic architecture and natural setting of Fort Mason, the Outdoor Exploratorium developed a *proximity* approach to graphic design. Proximity graphics use typographic strategies and image layouts designed to be clear and legible at close range but muted and unobtrusive at greater distances.

vernacular materials – subtle color

The Fort Mason shoreline has a strong marine industrial character; the predominant architectural materials are concrete, steel, and glass. Mooring bollards, roll-up steel doors, boat hoists, and railway tracks are some of the many landscape elements that testify to Fort Mason's former role as a major shipping and warehouse center. The Outdoor Exploratorium's exhibit signage is designed to harmonize with and compliment these vernacular forms and materials.

Metals with a natural finish or rusted patina are the basis of the materials palette for Outdoor Exploratorium signage. Bright fields of color are generally avoided. Clear acrylic cylinders or panels are used as housings and substrates in a way that allows background colors from the environment to blend with the signage. Industrial brackets, fittings, and hardware are used to integrate the graphic armature with the surrounding landscape.

ambushed fixtures

By re-staging objects already existing in the environment into graphic display devices, an aesthetic can be crafted that both stands out and recedes. Simple, utilitarian objects—parking lot gates, newspaper stands, or the door of an abandoned building—can be re-invented as interactive devices that encourage visitors to engage in an exhibit experience and become more astute observers of their surroundings.

A newsstand cabinet widely used at Fort Mason Center was graphically re-staged into a device that vends portable field guides in the *Portable Observatories* exhibit.

The atmospheric angle gauge on the *Sky Mirror* exhibit and the salinity meter fountain on the *Tasting the Tides* exhibit integrate graphic explanation with instrument-like experimentation and investigation.

graphic instruments

When a graphic is not just "about" an exhibit, but is itself a manipulatable interactive instrument, it invites play and exploration in a way that static exhibit labels do not. If visitors are given an opportunity to measure air temperature along a heated wall, change the angle of a mirror reflecting the sky, or alter the salinity level of a drinking fountain, they can become more engaged, active investigators. The signage can be less intrusive because the experience is more compelling.

SITE NAVIGATION

Brian Connell
Project Developer

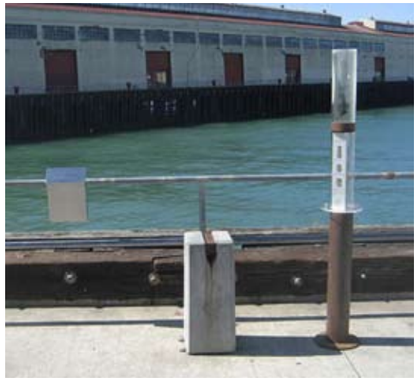
Unlike many outdoor settings, where exhibits and interpretive materials are clustered around a central location, Outdoor Exploratorium exhibits are widely dispersed throughout a 13-acre site at Fort Mason Center and at different points along the Golden Gate Promenade, an east-west path across Upper Fort Mason. How do visitors find and connect exhibits distributed throughout a variety of locations in a diverse urban waterfront environment?

orientation kiosk

A detailed map, project overview, and description of Outdoor Exploratorium exhibits is located at the main orientation kiosk across from the Fort Mason Center office. Jointly used by the National Park Service, Fort Mason Center, and the Exploratorium, the kiosk also provides visitors with historical interpretation, maps, and a directory to organizations and event locations.

project maps

Visitor orientation to the Outdoor Exploratorium is also provided by paper maps located in boxes mounted next to the exhibits. Portable maps are especially useful in navigating from the exhibit collection at Fort Mason Center to exhibits located along the Golden Gate Promenade in Upper Fort Mason.



station icons

Project navigation in Upper Fort Mason is fairly simple, because Outdoor Exploratorium exhibits are all visible along the main pathway that connects the eastern and western entrances to the Park.

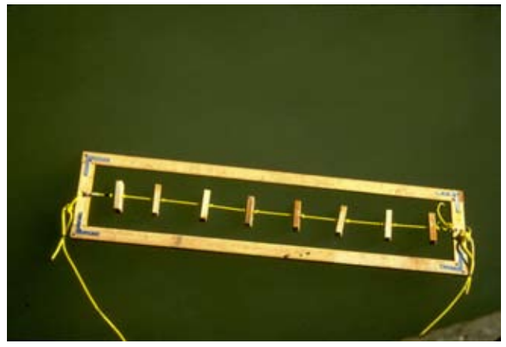
In contrast, Fort Mason Center is an architecturally dense landscape with exhibits widely dispersed in a variety of locations. To aid in orientation and recognition, a majority of the Fort Mason Center exhibits use a prism cylinder station icon for exhibit signage. The tall vertical columns of the prism cylinders help visitors find exhibit locations among the buildings, alleyways, and waterfront pier structures that characterize the Fort Mason Center shoreline.

ARTISTS AS COLLABORATORS IN THE OUTDOOR EXPLORATORIUM

Peter Richards
Principal Investigator

The Exploratorium has a long history of engaging artists in all aspects of its program activities. The museum's Artist-in-Residence Program has supported many art/science collaborations, research projects, and the creation of new exhibits and installations for the public. The Outdoor Exploratorium provided a unique opportunity to work with artists in a varied outdoor environment where history, the natural world, and the built environment come together.

Sea as Sculptress structure



www.exploratorium.edu/outdoor/sea_as_sculptress

THE SEA AS SCULPTRESS DATA BANK
Ruth Wallen

One of the museum's earliest artist research projects was Ruth Wallen's investigation of San Francisco Bay's water quality and its impact on marine life. In 1979, she used macro-photography to document patterns of marine growth on introduced floating structures over the course of a year. She studied three sites, including Fort Mason, Alcatraz Island, and China Basin on the city's southeastern waterfront. She took hundreds of photographs documenting plant and animal growth for four full seasons. Many of these images were used in her Exploratorium performance *The Sea as Sculptress*.

Almost three decades later, as we began working at Fort Mason, we reconnected with Ruth by chance and reached an agreement for her slides to become a baseline for analyzing contemporary growth patterns at Fort Mason. We thought her work would particularly complement the project's *Pier Piling Pivot* exhibit, a fender piling that can be raised to allow examination of the plants and animals of the Bay's intertidal zone. Ruth organized over 1000 images according to place and time, and in the process of identifying the organisms they depicted, she consulted with local scientists who immediately recognized the value of the work. No one had yet taken the time to do this kind of Bay study, and this data bank is already becoming a valuable research resource. When we first worked with Ruth in 1979, we had questions about the transitory nature of her project. Some suggested that the project's only outcome might be her performance, an event experienced only by a limited audience. At the time, we wondered if there was sufficient justification for investing in such a project. Now, with the benefit of hindsight and in light of the Outdoor Exploratorium, we can answer this question with a resounding *yes*. Her work with us is a great example of the importance of careful research for both artists and scientists—even if there is uncertainty about its future value.

THE BAY MODEL
Oliver Fringer, Dan Collins, Gene Cooper

Over the Exploratorium's 40-year history, we've developed a broad network of people with whom we share common interests—and with whom we've either already collaborated or hope to do so. Oliver Fringer is such a person: he works in Stanford University's Engineering Department and has developed a process for using computer modeling to understand estuarial bodies of water. He demonstrated several of these models for us at about the time we started our work at Fort Mason, and mentioned his desire to create such a model of San Francisco Bay. At the same time, we were searching for ways to link experiences on the Exploratorium floor to Fort Mason's Outdoor exhibits one mile to the east.

As our conversations became more substantial, we suggested that Oliver contact Dan Collins, an art professor at Arizona State University specializing in 3D visualization and prototyping. Dan was very excited, and, in turn, brought in another colleague, Gene Cooper, a former student and a specialist in developing interactive virtual-reality content for clients like the National Park Service. For the final piece, Oliver and another colleague, Vivien P. Chua, researched the content, Dan developed a 3D model of the Bay, and Gene designed and built the interface between the computer model and projection system. The team worked with a number of Exploratorium exhibit staffers to design the control module and exhibit furniture.

The Outdoor team envisioned this exhibit as more than simply a visualization of the fluid dynamics of San Francisco Bay; we also saw its potential as a platform for visualizing other kinds of data related to the area, including wind and weather patterns, flight patterns for the region's airports, shipping traffic, water delivery, and more. We are confident that our network of friends and collaborators will provide the expertise, knowledge, and inspiration to help us fulfill this vision.

HARNESSING OUTDOOR EXHIBITS FOR TEACHERS AND STUDENTS

Modesto Tamez
Exploratorium Teacher Institute
Sebastian Martin
Exhibit Developer

The Exploratorium's cavernous indoor space has inspired and educated several generations of visitors since it opened in 1969. We have found volume and darkness to be integral and defining attributes of our institution—but the Outdoor Exploratorium brings the museum's approach to hands-on learning outside, into the light of the wider world. Frank Oppenheimer, the Exploratorium's founder, wanted average citizens to be aware of the subtleties of their surroundings and hoped that the experience of the Exploratorium would extend beyond the building's walls. The creation of the Outdoor Exploratorium at Fort Mason is our most ambitious attempt yet to take phenomena-based science learning outside, to where people work and live.

The primary function of the Exploratorium Teacher Institute is to teach middle- and high-school teachers that actually *doing* science is better then simply *talking* science. Institute educators were extremely excited about the opportunity to work with the Outdoor team as they refined and built exhibits. Specifically, we've been working with the team's exhibit developers to find ways in which classroom teachers could see the value of having students discover that science is everywhere—and that they could create exhibits for exploring natural phenomena themselves, in their own schools and classrooms.

This collaboration provided several challenging opportunities for innovation. Beyond leaving the museum's familiar workshop and exhibit floor (Fort Mason is about a kilometer away from the Exploratorium), this project represented a key opportunity for teachers to play a role in the development of an exhibit collection from its inception. As part of this role, we had the ability—and the responsibility—to give ongoing feedback to exhibit developers. In addition, we created several Saturday teacher workshops to experiment with using outdoor exhibits to teach about natural phenomena.

One of our main goals was to have teachers try outdoor exhibit prototypes and give feedback from an educator's perspective, but another was to come up with "snack" versions of the activities. Science Snacks are smaller versions of our floor exhibits that can be transported to schools, so that students from around the area can use them to build knowledge and inquiry skills without having to journey to the museum. We helped the developers design these activities to maximize students' ability to see their own outdoor worlds in fresh new ways.

For example, one of the first exhibits on which we worked with the team was *Lift*, an array of light airfoils suspended on a series of vertical cables. We found that when the wind was strong, our teachers expected to see all the airfoils rise uniformly, forming a straight horizontal line. To their surprise, the foils rose at different rates and held at different heights, giving a tangible indication that wind speeds may vary considerably over even short distances. To test out Snack versions of this experience, we gave about 30 teachers meter sticks with light plastic ribbons attached to one end. The teachers stood at different locations in a field and raised their sticks aloft—and immediately noticed that even though they stood close to each other, the directions and heights of their ribbons were markedly different. Quick, rough, and playful experimentation like this helped us create versions of the exhibit that could be easily duplicated at many schools and classrooms with a minimum of time and materials.

Our collaboration with the Outdoor team made it possible for us to create Snack versions of many of the final exhibits installed at Fort Mason, and thus to enhance teachers' abilities to bring both specific content ideas and more general inquiry skills to their students. And to our great delight, many of the teachers who participated in our Outdoor workshops have since written to tell us that not only have they tried many of those Snacks in their own classrooms, they have also been inspired to search for other phenomena that they and their students could observe and discuss. This is perhaps the most fundamental lesson of all: getting teachers and students to play with ideas and experiment with phenomena develops its own momentum—and creates new and unforeseen opportunities for learning.

doing hands-on science outdoors

Steve Gennrich
Project Manager

In 2006, the Outdoor Exploratorium team established a partnership with the Golden Gate National Recreation Area and San Francisco's Fort Mason Center to create outdoor science exhibits at Fort Mason. The team's first priority was to learn as much as possible about this unique site—a location steeped in history and rich with the phenomenological raw material that could serve as a foundation for compelling exhibits. The team spent several months exploring and researching Fort Mason, but we also made many local friends. As the team began working on exhibit ideas, these friendships matured into working partnerships. The hours we spent at Fort Mason not only helped us build exhibits reflecting the unique natural science opportunities offered by the site, but made us part of a new community as well.

Volunteers painting the Searchlight Building for *House of Days*

Before our partnership with GGNRA and FMC, the Outdoor Exploratorium team had spent several years discussing exhibit ideas and development challenges with organizations throughout San Francisco. These experiences honed our observing and presentation skills, but they also provided a collection of exhibit ideas to share with potential partners. When the opportunity to work with the GGNRA presented itself, their deeply respected Superintendent, Brian O'Neill—known within the National Park Service for embracing new ideas—fully supported the team's goal of creating experiences through which visitors could explore and understand their surroundings. However, the team still needed to generate excitement about each specific exhibit idea among the many departments playing a role in making the project come together.

The National Park Service's mission statement notes the goal of "preserv[ing] unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations." The Outdoor Exploratorium focused on encouraging people to become better observers of the world around them. Here is where our missions aligned: our many discussions about exhibits and their goals underlined our mutual desire to foster a greater appreciation of the environment—and ultimately to inspire people to preserve and protect their natural resources.

Jay Eickenhorst, our GGNRA liaison, helped us understand processes for approving new infrastructure. GGNRA's Cultural Resources Group was created to "ensure that the effects of projects on historic properties and cultural resources is understood and taken into account during project planning, development and implementation." When the team agreed on the first five exhibits we wished to present, we met with the director of this group to review those exhibits before presenting them to the Cultural Resources Group. We presented later exhibit ideas in additional batches until all twenty exhibits had been discussed and approved.

Exploratorium educator Modesto Tamez meeting with students at Fort Mason

However, GGNRA couldn't give final approval until the entire project scope was presented to GGNRA's Project Review Board. This presentation required complete descriptions of *all* proposed exhibits, including details of the site modifications required to accommodate them. After the project was approved, GGNRA appointed Project Manager Aaron Roth to work with us on final pre-installation approvals. Aaron helped craft a Special Use Permit documenting our relationship and the terms under which the exhibits would remain on National Park land.

We also developed checklists for review by other key groups. For example, GGNRA's Chief of Education and Interpretation worked with us to approve graphics and signage associated with the exhibits; Natural Resources staff reviewed exhibits for potential wildlife impacts; the GGNRA's Accessibility Manager signed off on exhibit design details; and installation details were reviewed for potential impacts on the site's historical integrity. Because of our team's limited size, we had to install the exhibits in small batches, so we created signoff matrices to track the approval process, allowing the team to start installation on approved exhibits while newer pieces were being reviewed.

Creating a working relationship with facilities, maintenance, and groundskeeping

Installing a wave reflector prototype

Demonstrating the *Tasting the Tides* exhibit

crews at Fort Mason became extremely important during exhibit installation. Fort Mason facilities staff completed major infrastructure modifications required for many exhibits, such as running power and plumbing lines to exhibit sites. GGNRA grounds crews helped us map underground utilities and showed us how to trench with minimal impact. We also enlisted the welcome assistance of the San Francisco Conservation Corps to clean and retrofit an abandoned building for an exhibit site. While working together on installations, facilities and grounds crew staffs began to embrace the ideas behind the exhibits themselves; in fact, our collaborations have continued in the form of an ongoing dialogue about maintenance and improvement between Fort Mason and Exploratorium staff.

Many exhibit-specific partnerships were essential in ensuring that exhibits reached their full potential. While developing the *Bridge Thermometer* exhibit, we partnered with the Golden Gate Bridge District, NOAA, and Haselbach Surveying to gather data on the Bridge's movements in response to wind and temperature. Marine biologists from the Bodega Marine Laboratory and the California Academy of Sciences helped us identify organisms growing on the *Pier Piling Pivot*. In turn, the Outdoor Exploratorium team looks forward to working with the Golden Gate Bridge District and NOAA on upcoming projects.

Once the collection was near completion, Fort Mason staff worked with the Exploratorium's Public Relations, Graphics, and Marketing Departments to announce the collection's debut with an extensively-publicized event. These groups continue to work together to publicize new exhibits, organize group tours, create signage, maps, and an audio guide, and open an ongoing workspace for exhibit repair and maintenance. Collaborative skills like these will be key to our success in working with future partners—and in preparing for the museum's upcoming move to San Francisco's Embarcadero.

Most broadly, collaborating with partners forced our team to revise our traditional ways of working. GGNRA's approval processes didn't allow our prototypes to evolve continuously, as they often do on the museum floor. Instead, our partnerships required us to start with proof of concept prototyping, present renderings of exhibits as they would appear onsite, and receive plan approval—all before final production. This was a new way of working for us, and it not only helped us refine our presentation skills but also taught us new ways of thinking about developing strong exhibits. Similarly, communicating designs to structural engineers and fabricators led to improvements in our engineering and design capabilities.

The exhibits making up the Outdoor Exploratorium at Fort Mason provide a powerful foundation for innovative thinking about future projects and collaborative opportunities. Understanding our partners' goals, skills, and institutional personalities has been a fundamental part of moving this project from intriguing concept to inspiring reality.

EVALUATING OUTDOOR EXPLORATORIUM EXHIBITS

Joyce Ma
Senior Researcher
Toni Dancu
Research Associate

Evaluation of the Outdoor Exploratorium began in 2001, years before the project's final realization as a set of exhibits at Fort Mason. The Exploratorium has a long history of evaluating visitor exhibit experiences to better understand visitor reactions and incorporate their feedback into exhibit development. But the Outdoor project presented both opportunities and challenges that we had rarely encountered within the more familiar walls of the museum—and each new phase of the project raised different questions.

Originally, the Outdoor Exploratorium was conceived as a space adjacent to the museum's current location at the Palace of Fine Arts. As such, our early evaluation efforts focused on front-end studies designed to identify visitors' outdoor behaviors and expectations. In addition to using traditional interview methods, we also experimented with other ways of learning about outdoor behavior and specific noticing techniques, including open-ended noticing activities to gauge noticing behaviors and expert-led "noticing tours" (e.g., a mushroom tour led by a naturalist; a writer-led poetry walk) to gain a focused look at visitors' interests in particular content areas.

Although not all findings from these studies found direct application in the final exhibits, we learned valuable lessons about supporting outdoor noticing. In particular, we identified some of the reasons visitors spent time noticing outside, including wanting to be in attractive areas, participate in independent exploration, and see things they hadn't noticed before (or familiar things from new perspectives). We also discovered some impediments to exploring and noticing outside, such as limited time, worries about safety (outdoor environments not always being well-bounded or predictable), and self-consciousness about activities that might seem unusual (such as using a magnifying class to examine dirt). Our findings also helped us redefine project content areas. For example, before our front-end studies, the Outdoor Exploratorium was primarily focused on natural phenomena, but evaluation results led us to broaden the project's scope to include the built environment as well.

In 2004, as active exhibit prototyping began, the project's final location was still uncertain. This (and the related fact that the eventual site would be a key factor in defining the exhibits themselves) spurred us to rethink our approach to prototype evaluation. Typically, iterative formative evaluations are used to inform and improve a particular prototype in a specific context, and these findings are often not generalizable. But given our uncertainty about site, we sought to use formative evaluation to study promising *techniques* to foster noticing that might later find broader application.

For example, we looked at different ways of framing phenomena to help visitors notice particular aspects of the outdoors—and found that framing was not always effective. When framing worked, it tended to help people move into position to see something in their surroundings, to think about composition, or to focus on only one portion of the larger landscape. Some of the prototypes developed and evaluated during this period became part of the final set of exhibits installed at Fort Mason; some served to inspire the final exhibit collection; and others never led to complete exhibits but did generate ideas for learning about ways of encouraging visitors to notice and think about outdoor phenomena.

It was also during this period that we began to envision the Outdoor Exploratorium as a set of exhibits at one or more distributed sites away from the museum itself. We know a lot about Exploratorium visitors, but considering remote locations required us to reevaluate our audience assumptions. The team thus began asking fundamental questions about people who might use our exhibits: who are they? What are they doing there? When are they there? We were particularly inspired by the work of William Whyte, who conducted observational studies in the 1970s of how people use New York City plazas[1], and we conducted our own set of informal observations to learn about the "social life" of the candidate sites our exhibits might occupy.

These observations taught the team two key lessons. First, the demographics of potential visitors would be different from the Exploratorium's typical audience. Outdoor exhibits at new sites would likely be seen by a higher percentage of adults, and by a higher percentage of individual (rather than family group) visitors. Furthermore, visitors to outdoor exhibits away from the museum would likely have a wider variety of reasons to be outside, and thus to be pursuing a broader range of activities. Potential visitors could include people traveling to and from work, eating lunch during a break, sunbathing, sitting and chatting with others, or simply taking in the view. Some people might pass through the area every weekday; for others, the site could be a stop during their only San Francisco visit.

Second, sites are not monolithic. Especially for a large site, different sub-areas might have very different audience characteristics: a Tai Chi club practicing in one place, teenagers performing stunts on their skateboards in another, runners sprinting along a section of path. Furthermore, characteristics like these tend to change throughout the day and week. Characterizing a site's complexities provided important information for exhibit development and placement.

By 2006, it was clear that the main body of Outdoor Exploratorium exhibits would be installed at Fort Mason, allowing us to focus our primary development and evaluation work. Accordingly, we refocused formative evaluation efforts on improving individual

exhibit experiences. Initial formative evaluations at Fort Mason employed a rapid prototyping and evaluation technique[2] best suited for decision-making in early stages of exhibit development. This collaborative method allows developers and evaluators to address each visitor's difficulties before the next visitor's experience and make rapid changes in prototype design. This type of formative evaluation helped the team identify critical issues with exhibit concepts and challenged our assumptions about text and label design.

The team began final exhibit installations at Fort Mason in the fall of 2008. In anticipation of an early 2009 completion date, we asked Beverly Serrell, principal at Serrell and Associates, to conduct a summative study beginning in October 2008. Ms. Serrell brought a wealth of expertise in exhibit evaluation, including conducting summative evaluations for The New York Hall of Science's Science in the City, which placed museum exhibits in the streets of New York City. However, due to delays in exhibit approval and installation, only seven of the planned twenty exhibits were ready for summative evaluation by the time Serrell was to begin data collection. In the end, we proceeded with the evaluation, but also asked that the process identify areas for remediation. This summative evaluation of the first seven exhibits, therefore, (a) provided a preliminary understanding of how well a subset of the collection met the project's visitor goals, and (b) informed final development of these exhibits as well as the remainder of the collection.

In terms of achieving key project goals, the first summative evaluation found that "[a]ll seven of the exhibits evaluated in this study succeeded to one degree or another at encouraging noticing and promoting noticing skills with visitors... Among the intended goals, noticing skills were the strongest outcome with the participants in this study. Enabling noticing skills was an unusual and exciting experience for many people. This goal is very suited to helping visitors feel competent and interested in outdoor natural phenomena—a worthy visitor outcome for many science museums. The OE exhibits can serve as good models for what is possible." On the other hand, however, "[t]here was less evidence for the other two goals of helping visitors 'explore complex systems and interactions at play in an outdoor environment' and 'come to a deeper understanding of the phenomena by applying scientific concepts and principles'."

Serrell strongly recommended that the team focus remediation efforts on developing clearer information architecture and wayfinding systems and making sure that formative evaluation was conducted on exhibits not yet installed. The team took these evaluation recommendations to heart. During this period, formative evaluation focused on identifying potential visitor difficulties with using, accessing, or understanding each exhibit and iteratively improving those exhibit experiences. The team also returned to the previous set of exhibits to assess the effectiveness of remediation steps resulting from the first summative evaluation.

Building on these findings, Wendy Meluch of Visitor Studies Services conducted a second evaluation in the spring of 2009. By this time, fourteen exhibits were installed at Fort Mason, and a new information architecture and wayfinding system was in place. VSS interviewed visitors who used most of these exhibits as well as visitors cued to use a cluster of three exhibits in close proximity. Evaluators also unobtrusively observed visitors at several exhibits.

Overall, the second summative evaluation found the Outdoor Exploratorium "fun and engaging for users." However, some goals were met more clearly than others. More specifically, VSS found that approximately 65% of those interviewed described the noticing skills they used at exhibits or as a result of their exhibit experiences. (This is consistent with other observations suggesting that visitors were purposefully engaged with looking and comparing.) A smaller percentage of visitors interviewed (42%) discussed how the exhibits encouraged them to notice their surroundings. More than 80% either described or articulated an awareness of the complex systems underlying exhibits, but only 32% were able to describe in some detail the *relationships* they noticed as a result of using the exhibits. Finally, almost half of those interviewed (48%) expressed an appreciation or understanding of the outdoor world as a result of using the exhibits; a smaller group (22%) mentioned science as a way of studying and understanding the world. In addition, although this summative evaluation was not intended to be a remediation study, visitor interviews did suggest that people wanted more help finding the exhibits at Fort Mason, and that the collection could benefit from additional attention to the current wayfinding system.

At the Exploratorium, visitor evaluation has long been an integral part of the exhibit development process. However, evaluation was especially critical to addressing this project's many unknowns. In particular, evaluation was key to learning how to foster and support visitors' outdoor noticing skills, to characterizing new audiences, and to working with external partners in developing exhibits at a remote site. Addressing these challenges required us to experiment with methods that we rarely use inside the museum. In addition to informing this project, then, we anticipate that some of the evaluation approaches used for the Outdoor Exploratorium will find application in future projects—indoors and out, at the Exploratorium and elsewhere.

Detailed information about the project's summative evaluation processes and results can be found at: www.exploratorium.edu/partner/pdf/oe_summativeP1.pdf and www.exploratorium.edu/partner/pdf/oe_summativeP2.pdf.

1 Whyte, W. H. (1980). The Social Life of Small Urban Spaces. Washington, D.C.: Conservation Foundation.

2 Medlock, M.C., Wixon, D., McGee, M, & Welsh, D. (2005). The Rapid Iterative Test and Evaluation Method: Better products in less time. In Bias, R.G. & Mayhew, D. (Eds.), Cost-Justifying Usability: An Update for an Internet Age (2nd Ed.). San Francisco, CA: Morgan Kaufmann.

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