DESIGNING ACCESSIBLE INTERACTIVES

An Inclusive Process for User Testing

Caitlin Ballingall, Sheri Levinsky-Raskin, Barbara Johnson Stemler, Jessica Williams

The year 2018 marked the 60th commissioning anniversary of a unique Cold War veteran. From 1958 until 1964, the submarine USS *Growler* lurked off the east coast of the Soviet Union with an all-volunteer crew of 95 to 100 men. Their mission: stand ready to launch guided nuclear missiles against Soviet military targets (fig. 1). On view at the Intrepid Sea, Air & Space Museum in New York City, *Growler* embodies the tensions and technology of the Cold War and represents the beginning of what we know as the nuclear triad.[1]

Moored in the Hudson River, *Growler* shares its pier with its much larger and better-known neighbor, the aircraft carrier *Intrepid*. Since opening to the public in 1989, *Growler* consistently ranks as one of the museum's most popular exhibits (fig. 2). Squeezing through the submarine's tight passageways, visitors marvel at the fortitude of the men who lived and worked in such cramped quarters while undertaking a dangerous mission. However, the physical constraints that define submarine life also limit access. Groups, families with small children, and visitors with physical disabilities or claustrophobia have been unable to experience this artifact.

Faced with this challenge, and driven by a commitment to accessibility, the museum utilized a rigorous formative evaluation process to ensure that such visitors would have access to key elements about the

1 The nuclear triad is a combination of nuclear-capable bombers, land-based ballistic missiles, and submarine-based missiles. Each leg of the triad provides a different capability, presumably deterring adversaries from attempting a first strike.

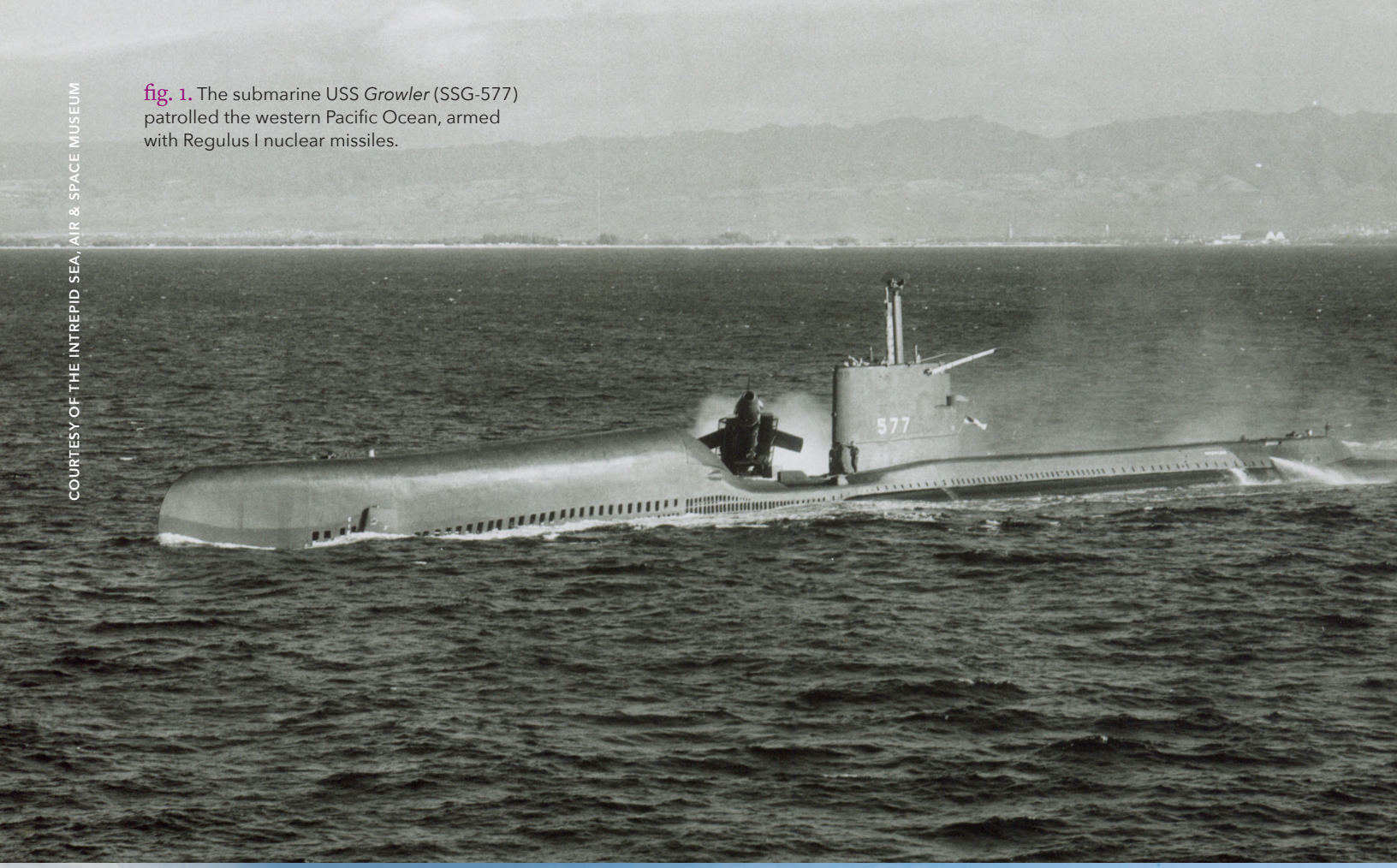

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fig. 1. The submarine USS *Growler* (SSG-577) patrolled the western Pacific Ocean, armed with Regulus I nuclear missiles.

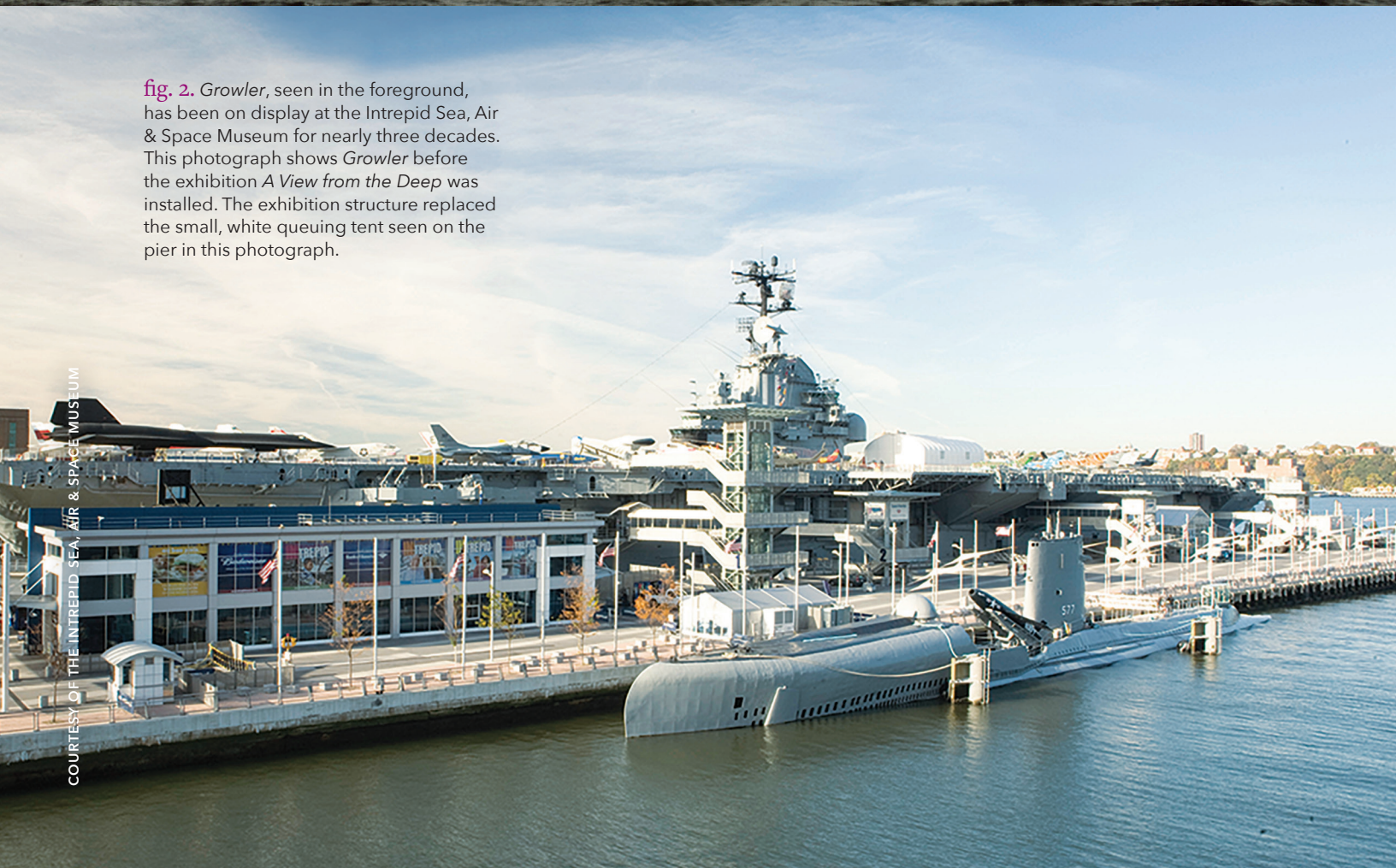

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fig. 2. *Growler*, seen in the foreground, has been on display at the Intrepid Sea, Air & Space Museum for nearly three decades. This photograph shows *Growler* before the exhibition *A View from the Deep* was installed. The exhibition structure replaced the small, white queuing tent seen on the pier in this photograph.

Life on *Growler* offered no shortage of compelling avenues for interpretation. Two, though – both of which focused on sound – rose to the top through curatorial research coupled with crew recollections.

submarine environment and life aboard even if they were unable to physically enter the vessel. We allowed ourselves the time to test exhibition elements in an effort to determine how well we met our objectives relating to physical and sensory accessibility, learning goals, and knowledge scaffolding. The result was a process for testing interactive exhibits that welcomes individuals with disabilities as active participants.

A Need and an Opportunity

To commemorate *Growler*'s 60th anniversary, the museum decided to create a new exhibition on the pier that would explore *Growler*'s significance in the Cold War. At the core of the exhibition, titled *A View from the Deep*, are first-person accounts with *Growler* crew members and their wives, drawn from an IMLS-funded oral history project. These interviews capture the personal experiences of the men who served in such physically and mentally demanding conditions, and the impact of this service on their families.[2]

In designing the exhibition, the museum prioritized accessibility. Museum staff invited individuals with disabilities, and their families, to experience and provide insights into interactive elements. Focus groups represented audiences who regularly attend specialized programming and events for individuals with disabilities. Located in a structure on the pier, the new exhibition would serve as an introduction to *Growler* or as a stand-alone experience for visitors who choose to not enter the submarine. Because submarine service is so rich in sensory experiences, the museum wanted to create multimodal exhibit elements that would immerse all visitors – regardless of ability – in these unique, incomparable aspects of sailors' lives.

A year before the exhibition opening, the museum assembled an in-house project team that brought together curators, exhibition designers and fabricators, internal accessibility specialists, and research and evaluation professionals. The museum also teamed up with the Sensory Computation, Experimental Narrative Environments Lab at the Stevens Institute of Technology (SCENE Lab for short) to develop two immersive, accessible experiences. SCENE Lab specializes in the development of immersive spaces. Their particular expertise in presenting spatial audio, as well as visualizing sounds, supported the museum's efforts to think creatively about immersion and accessibility. SCENE Lab collaborated with the museum's staff team to conceptualize exhibit elements and brainstorm strategies for access. Designing prototypes for user testing was a central part of SCENE Lab's role.

Before this project, we had tested new exhibit ideas with visitors using surveys and intercept interviews; we had also tested museum map design with users. However, these prior projects were not implemented with accessibility as a specific area of focus.

2 In 2016, the Institute for Museum and Library Services (IMLS) awarded a Museums for America grant to the Intrepid Museum for a project that captured oral histories with *Growler* crew members and then transformed the interviews into exhibition media.

The *Growler* project presented the museum with a new opportunity to further explore visitor-centered design practices with direct input from visitors and community members representing a range of physical and sensory disabilities. While the museum's exhibit design team regularly follows guidelines for accessible design, the user testing offered deeper insights into visitor needs, ensuring that visitors with a disability or heightened sensitivities to their environment could have a rich and meaningful experience.

From Concept to Prototype

Navigating hundreds of feet below the ocean's surface. Avoiding detection by a watchful enemy. Launching and guiding nuclear weapons toward their target. Cooking for 100 hungry men in a tiny galley. Life on *Growler* offered no shortage of compelling avenues for interpretation. Two, though – both of which focused on sound – rose to the top through curatorial research coupled with crew recollections. The first was the vital importance of sonar to *Growler*'s mission. In the black depths of the ocean, *Growler* crew members relied on passive sonar – listening to underwater sounds, without transmitting – to identify other vessels based on their unique sound profiles. The second was the sensation and meaning of *Growler*'s own sounds and vibrations. Numerous crew members described becoming attuned to these sensations, which were linked to their very survival. They told crew members when the sub's systems were humming along as they should be – or not.

These topics – sonar and everyday sounds and vibrations – became the basis for two key exhibition interactives. For sonar, we decided with SCENE Lab to create a game that challenges visitors to identify the underwater sounds that *Growler*'s sonar technicians would have heard. During *Growler*'s time, sonarmen truly relied on their own ears and memories; their equipment did little to help them differentiate sound sources. This game underscores how these few, highly trained men shouldered an enormous responsibility for the safety of the submarine. For the sound and vibration interactive, we conceived of a "sound cube" – a small room that would simulate the sounds of a submarine at sea. *Growler* is far quieter and stiller than it was during the Cold War, and this interactive would help visitors get a feel for an active submarine. It would also show how the submarine's sounds and vibrations varied depending on where you were standing or what machinery was operating. These two concepts, while central to submarine life, posed a challenge for accessibility: both relied heavily on the sense of hearing.

With two approved concepts, the team began discussing the design. We drew upon our collective experience while considering everything from the exhibit footprint, to interface design, to casework, to content. SCENE Lab presented the team with concept drawings, and we suggested modifications. Once we agreed upon a design direction for each interactive, SCENE Lab began designing prototypes for user testing. Although there were other interactive elements, funding and time constraints compelled us to make choices about which elements to test. We opted to test these two concepts because they would be focal points of the exhibition, and we had special concerns about accessibility.

We worked with SCENE Lab to ensure that the prototypes captured the important features of each interactive that we wanted to test. The first prototype consisted of a console modeled after *Growler*'s sonar equipment. A game, played on a touchscreen,

The vibrations added an additional sensory element that would be detectable by visitors who are hard of hearing.

put visitors in the role of sonar technician. Visitors identified underwater sounds common to *Growler*'s patrol area. To enhance the experience for visitors who are hard of hearing, as well as observers, a waveform visually depicted sound waves with curved lines and shapes on a separate screen. We presented the prototype to testers on touchscreens displayed on a folding table. Although we envisioned creating casework that reflected *Growler*'s sonar sets, we determined that the full buildout was not economical at the prototype stage. As a result, the touchscreen with the sonar game and the monitor with the waveform were presented side-by-side during the test. In the final version, the waveform would be displayed above the touchscreen.

The prototype for the "sound cube" evolved into a "sensory cube." Rather than simply play an audio track, SCENE Lab developed an ambisonic (surround sound) room with a vibration transducer embedded in the floor. The vibrations added an additional sensory element that would be detectable by visitors who are hard of hearing. Our exhibition design team fabricated the prototype room to the same scale that we envisioned for the interactive, complete with a floor that vibrated along with the soundscapes. Visitors entered the room and used a touchscreen to select from three soundscapes – engines running, crew's mess, and operating on the surface. The screen displayed a historical image and brief text that gave context to each soundscape. To save time, we left the speakers and framework exposed; both would ultimately be hidden in the final version.

Drawing upon Community

As SCENE Lab developed the two prototypes, the project team looked at historical attendance and programming data to identify groups of individuals to participate in usability testing. The museum engaged multiple individuals with different disabilities in order to amass as many perspectives as possible. We drew upon our longstanding relationships with communities and community organizations representing people with disabilities, amassed and fostered through years of community outreach and specialized and inclusive access programming for children, teens and adults with disabilities. The project team invited members of the museum's Autism Advisory Council, accessibility professionals, and citywide disability advocates to participate in usability tests. While accessibility was a priority, we also identified other user groups to include in the testing. We invited Navy veterans to provide feedback on the content. We also invited staff and general visitors to further identify usability concerns.

The entire test group was comprised of 28 people: 14 individuals with disabilities, three general visitors, six staff members, and five submarine and Navy veterans. In order to optimize accessibility within the design, the museum selected a test group that represented a diversity of abilities and needs for accommodations. Of the 14 individuals with disabilities, there were individuals with autism, individuals with a genetic physical disability, individuals who are hard of hearing, and individuals who are blind or have low vision. Half of those users were familiar with the museum, its physical space, collections and programs, while half were visiting for the first time.

Usability Testing

The museum's in-house staff of access specialists and research and evaluation professionals designed a usability test to evaluate the prototypes. Usability testing

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fig. 3. Museum staff observed users as they interacted with the prototypes. This user is testing the sonar interactive.

collects qualitative data, determines participant satisfaction, and identifies usability problems. The museum's research professionals selected this evaluation method because it requires few participants and can be conducted in the formative stages of development to allow for iterations. As few as five participants are needed to identify trends and provide insights that can drive decisions and change.[3]

Researchers wanted to gain insight into how users naturally interacted with the prototypes. The goal was to allow each participant's words and actions to create and direct the data collected. Each usability test lasted for 30 to 45 minutes. Test sessions were conducted in a one-on-one format, and in some cases in a group of two to three participants with a researcher facilitating. First, researchers observed participants' interactions with each prototype for five to 10 minutes (fig. 3). Facilitators encouraged participants to think aloud as they interacted with the prototype, and audio-recorded (and, in some instances, video-recorded) interactions for reference during the coding and reporting stages to follow.

During this observation phase, the museum's research and evaluation team documented their observations via written notes, specifically recording participants' emotions, i.e., confusion, delight, surprise, or happiness, while interacting with the prototypes. Staff referred back to audio and video recordings to incorporate direct quotations in the analysis, enhancing this user-driven data. Researchers standardized the data and organized comments according to:

3 Jakob Nielsen, "Why You Only Need to Test with 5 Users," *Nielsen Norman Group*, accessed September 4, 2018, www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/.

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- What are users interacting with the most? What are they avoiding?
- What aspects of the interactive appear frustrating or confusing? What aspects do the users want to experience more?
- What do the users do or say that indicates dislike or dissatisfaction?
- Are users doing anything unexpected?

Immediately after the 30- to 45-minute usability test, users participated in semi-structured interviews to gain feedback and greater insight into what users thought of the interactive prototypes. In these one-on-one discussions, the facilitator asked users follow-up questions about the behaviors they'd observed and the comments made by the user. Each participant was asked:

- What surprised you about your interaction with the prototype today?
- What do you want to keep or change? Explain.
- Did you discover anything new while interacting with the exhibit?
- Do you have any additional comments?

After the interviews, our research and evaluation team coded and cross-tabulated data and responses across all user groups, hoping to identify usability challenges and successes from both technical and accessibility standpoints. Their goal was to share these with the project team so that it could consider what modifications and adjustments needed to be made during this design and development stage.

Findings

The user testing quickly revealed trends. Many findings across all user groups – whether the individuals had a disability or not – confirmed correlations between best practices in exhibition design and inclusivity and accessibility. Practices often associated with accessibility are in fact beneficial to all visitors. Findings included the following:

- Color choices and contrast significantly affect readability. The prototype featured light yellow targets against a dark yellow background. Although there was contrast, the use of all yellow made the targets hard to see. The exhibit was altered to display white targets on a dark green background, improving contrast and visibility for the user.

fig. 4. Users test the prototype sound cube. Visitors stepped into a small room with brown, unfinished walls. Here, a woman and two children are exploring the touchscreen interface to select soundscapes. Researchers observed that users focused their attention on the touchscreen, not the submarine sounds or floor vibrations.

- Clear instructions and prompts set expectations for the experience and foster inclusivity by informing the visitor of what they will experience before entering the space.
- Images alongside text facilitate comprehension, especially for young children and users who are not proficient in English.
- Some users are uncomfortable using shared headphones and appreciate alternatives, such as audio handsets.
- Many users are sensitive to high audio levels, and requested a lower volume for the speakers inside the prototype.
- Variance in audio levels related to vibration intensity helps users to differentiate between unfamiliar sounds and sensations.

In some instances, certain user groups, most notably those with disabilities and submarine veterans, made specific recommendations:

- Provide audio descriptions and captions to enhance the experience for visitors who have low vision and are hard of hearing, respectively.
- For experiences that are primarily sensory, provide adequate contextual information, such as an introduction screen that provides historical information.
- Include an array of audio and visual options that provide variation and opportunity for comparisons, whether auditory, visual, or sensory.
- Allow ample space and legroom for wheelchair and scooter users as designs vary, depending on the user. Smithsonian Guidelines for Accessible Exhibition Design translate minimum and maximum requirements from the Americans with Disabilities Act into a museum-specific context, but it is helpful to conduct a real-world test with a wheelchair or scooter user.

Translating Findings into Practice

Many of the recommendations were straightforward and relatively easy to incorporate into the final designs. For instance, the SCENE Lab team adjusted colors and contrast to improve readability, and the curators rewrote texts to ensure clarity. Other findings provoked lively discussions. The sensory cube in particular prompted strong responses among users, staff, and designers. Here are just two examples of user feedback that provoked debate.

Weighing user feedback against curatorial priorities

The usability testing revealed that all users wanted more content and context in the sensory cube. Users had a difficult time orienting themselves in cube space. They were unsure if they were "inside" or "outside" the submarine when experiencing the sounds and vibrations. Users also made empathetic comments about the men that would have served on the submarine and posed questions about their daily lives to facilitators. Users suggested adding additional historical photos and background information to the touchscreen. However, these ideas contradicted the team's goal. We wanted to encourage visitors to focus on a few specific sensory experiences, believing that the daily lives of a submariner would be addressed elsewhere in the exhibit design. In addition, facilitators observed that visitors were highly focused on the touchscreen, and not the soundscapes or vibrations (fig. 4).

fig. 5. The final version of the sonar interactive has a touchscreen interface below (the green circle) and a waveform visualization of each sound on a monitor above.

ERIC VITALE

After serious consideration, the team took an approach that was contrary to the users' feedback and recommendations: they removed the touchscreen. SCENE Lab added a brief voiceover, drawn from the oral history collection of the *Growler* crew, that describes the sound and situational context to the start of each soundscape. A wall-mounted monitor displays a short descriptive text and a transcript of the voiceover. The redesigned sensory cube aligns with the curators' original goals while providing enough context to make the experience meaningful and accessible.

Evaluation and prototyping always takes time. Including a wide range of audience groups prolongs the process. Plan accordingly.

Considering contradictory feedback among user groups

Most users, including one who used a scooter, felt that the vibrations in the sensory cube were barely detectable. Yet two submarine veterans questioned the intensity of the vibrations in the prototype, recalling that these sensations were actually fairly subtle on board an operational submarine. The curatorial team reviewed the oral history collection and asked other veterans to share their memories of *Growler*'s sounds and vibrations. Their conversations revealed that vibration levels varied from compartment to compartment and depended on what equipment was operating. Weighing crew recollections against user feedback, the team determined that increasing the vibrations was essential for the user experience, even if this meant that the vibrations were more intense than they might have been on board. *Growler* crew members had months to become attuned to subtle sensations, while our visitors would engage with the sensory cube for just a few minutes. The designers introduced more variability in the vibration levels, erring on the side of exaggeration in some cases so that vibrations could be detected by visitors who use wheelchairs or scooters.

Driving Future Change

A View from the Deep opened to the public in May 2018. The usability testing process resulted in numerous improvements to the sonar station and the sound cube, which are among the highlights of the exhibition (fig. 5).

In the future, we hope to apply the usability testing process more broadly across an entire exhibition, not just for two interactives. By using a more holistic approach to understand how our target audiences experience all or most of an exhibition's interactives, we believe we can enhance access in two key ways. First, successful features can be incorporated across all interactive elements more systematically. Second, the needs of the various user groups are more equitably balanced across entire exhibitions and visitor experiences. For instance, if we find that many interactive elements feature sounds, as was the case in the *Growler* project, we might look to incorporate exhibits that focus on other sensory experiences.

Lessons to the Field

At the time of this writing, the museum has begun to evaluate the completed exhibition through post-experience visitor surveys and interviews. We have, though, already learned a number of lessons would like to share:

Build in enough time. Evaluation and prototyping always takes time. Including a wide range of audience groups prolongs the process. Plan accordingly.

Establish inclusive design goals from the start. Accessibility and inclusivity are more successful if they are considered from the beginning, not tacked on at some point along the way.

Develop relationships with target audiences. You cannot guarantee that members of your target audiences will walk through the door during public testing. To evaluate accessibility, the ability to call on individuals to serve as testers is crucial.

Share data across your museum. Findings proved to have wider implications beyond this project. Share what you have learned with colleagues in other departments, and reference existing data when embarking on new projects. Existing data may answer new questions and lay the groundwork for future studies.

Testing does not end at installation. Evaluate the final product within the context of the exhibition. Even if you cannot make major adjustments, the feedback will improve future projects.

The *Growler* exhibition project deepened the Intrepid Museum's longstanding commitment to accessibility in exhibition design. Welcoming individuals with disabilities into our user-testing process not only improved the design of our interactives, but it also gave our staff a more personal and nuanced understanding of the ways in which these visitors experience our interactive exhibits. This model of user testing will become part of our future design process, resulting in exhibits that are more multisensory, user-friendly, welcoming, and engaging for all of our visitors.

Caitlin Ballingall is Data Visualization Associate at the Intrepid Sea, Air & Space Museum in New York City.
cballingall@intrepidmuseum.org

Sheri Levinsky-Raskin is Assistant Vice President of Research & Evaluation at the Intrepid Sea, Air & Space Museum.
slevinsky-raskin@intrepidmuseum.org

Barbara Johnson Stemler is Director of Access Initiatives at the Intrepid Sea, Air & Space Museum.
bjohnson@intrepidmuseum.org

Jessica Williams is Curator of History and Collections at the Intrepid Sea, Air & Space Museum.
jwilliams@intrepidmuseum.org