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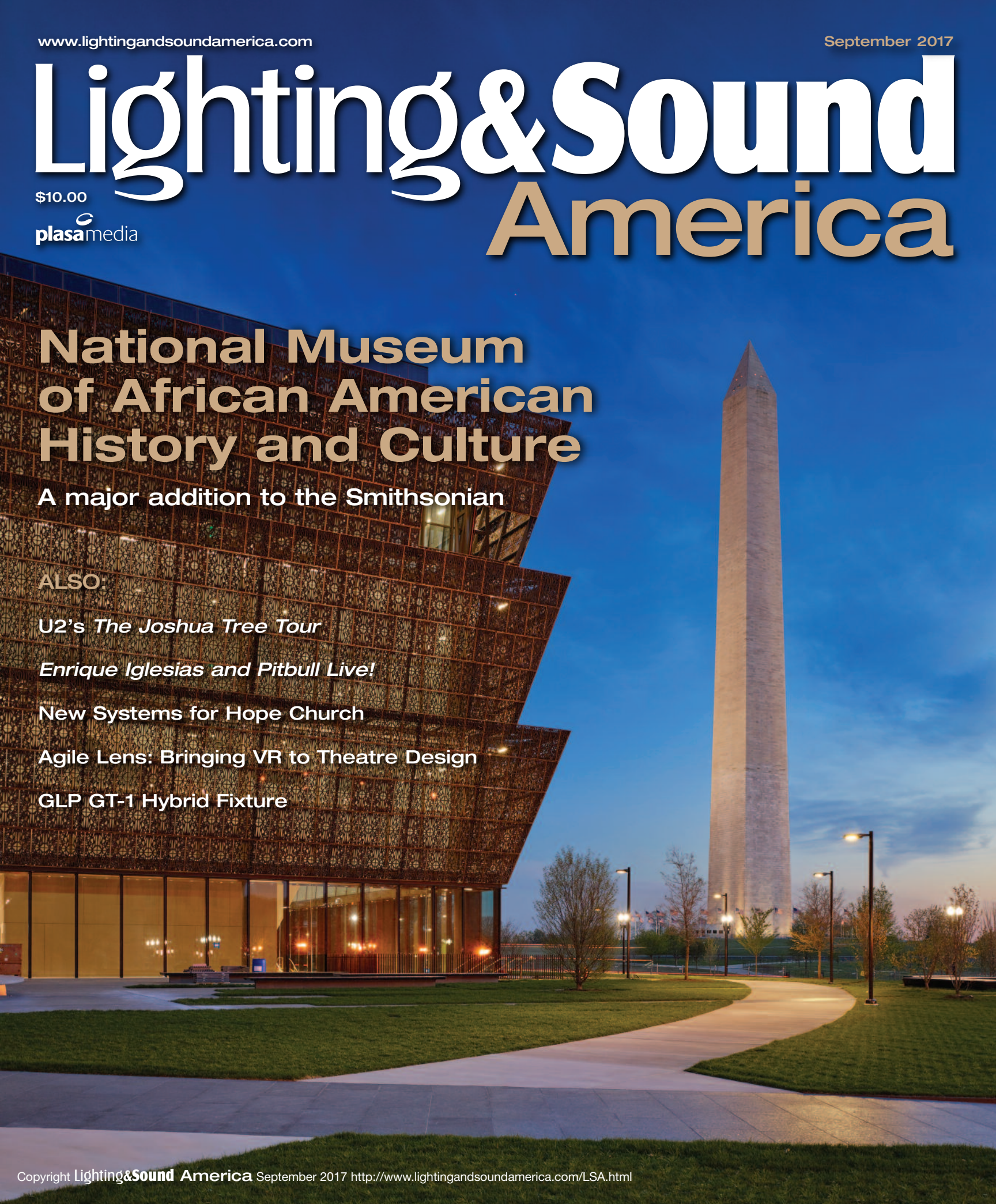

National Museum of African American History and Culture

A major addition to the Smithsonian

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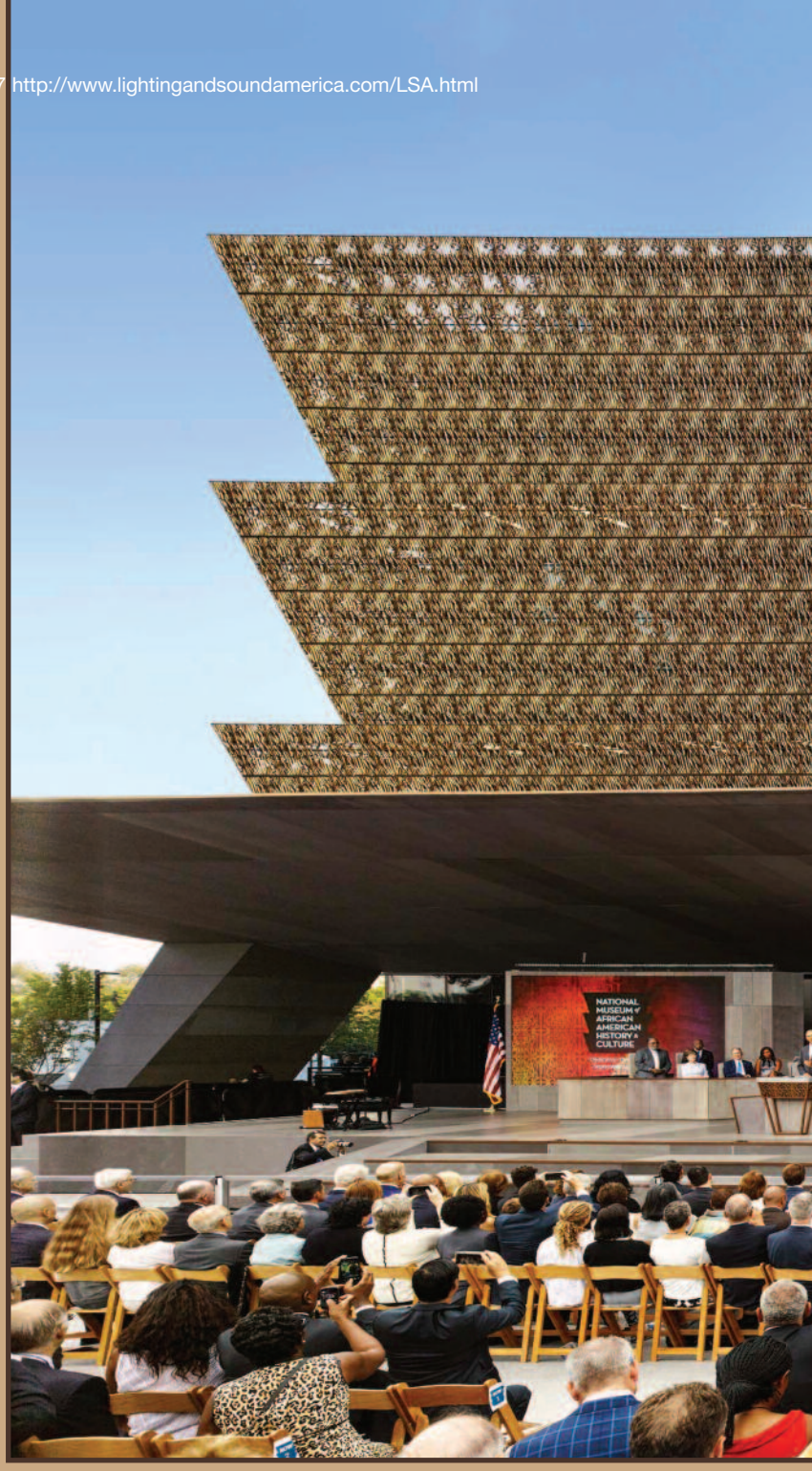


The National Museum of African American History and Culture is a stunning addition to the Smithsonian's lineup

By: Judith Rubin

The $540-million Smithsonian National Museum of African-American History and Culture (NMAAHC) opened on September 24, 2016, on a five-acre site on the National Mall, within easy distance of the White House and the Washington Monument. Located on Constitution Avenue between 14th and 15th Streets Northwest, NMAAHC is among 11 museums and galleries of the Smithsonian Institution located on the mall. Six additional Smithsonian museums and the National Zoo are found in the greater National Capital Area.

The 400,000-sq.-ft. building has five levels above ground and four below. It features 100,000 sq. ft. of exhibit space, with roughly 3,000 artifacts on public display. NMAAHC has fielded huge crowds since opening using timed ticketing. In February, reported attendance topped one million, with an average dwell time of six hours.

NMAAHC was 13 years in the making. In 2009, the museum's architectural team of Freelon Adjaye

The building's bronze exterior and triple-tier corona structure make it a striking addition to the landscape of the National Mall.

Photos: Alan Karchmer/NMAAHC

Bond/SmithGroup was selected; David Adjaye was lead designer, and Phil Freelon was architect of record. In 2011, Clarke/Smoot/Russell was chosen as the construction firm. Landscape design was by the team of Gustafson Guthrie Nichol. Groundbreaking took place in February 2012. The building has many sustainable elements and is expected to receive LEED Gold certification. The three-tiered, bronze-colored corona form of the building and its decorative, light-permeable facade draw upon African and African-American motifs.

In terms of the museum's contents, principal members of the creative team, interfacing with NMAAHC's internal team and curators, were Ralph Appelbaum Associates (exhibition design); Luce Group, LLC (exhibition lighting design); Electrosonic (AV systems design); and SH Acoustics (acoustics and audio system consulting). This team is now collaborating on the Obama Presidential Center, set to open in Chicago in 2019.

Production photos: Todd Kaplan

Design & Production provided fabrication, AV integration, and installation. Several key media elements for the exhibits (four films, 11 interactives, and 13 audioscapes) were developed by Cortina Productions; additional media/interactive elements were provided by Quatrefoil. Most media production was done under contract to the Smithsonian Channel, which gifted the media to the museum. Fisher Marantz Stone handled architectural lighting of the base building and the temporary exhibit gallery.

The Oprah Winfrey Theater was a separate-scope project with a different team, the principal members of which were Fisher Dachs Associates (theatre consultant) and Shen Milsom & Wilke, LLC (acoustician).

The Smithsonian internal team included Bryan Sieling (chief of design, assistant director for exhibition design and production, and acting associate director, office of project management and planning); Lynn Chase (retired director of project management); Andy Medalie, Carlos Bustamante, Dorey Butter, and Sabrina Kestell (project managers); Mike Biddle, Jimin Lee, and Dawn Neuendorffer (exhibit designers); Keith Madden (Oprah Winfrey Theater), and a team of curators, educators, collections managers and conservators. The museum's founding director is Lonnie G. Bunch III.

Because of the scope and scale of the museum and the sheer amount of equipment installed, it is not possible to detail every single aspect of the project within this article. We are spotlighting some of the major features, and have done our best to acknowledge providers, manufacturers, consultants, and creatives relevant to lighting, sound, AV, design, and tech design.

Seven-and-a-half miles a day

"This is definitely the biggest AV system I have ever encountered," says Patrick Rey, who, since December 2016, has been supervisor in charge of lighting and AV in NMAAHC exhibit spaces. He and his team of two others maintain the exhibit technology. Previously, Rey worked at the National Museum of Natural History.

The official count is 88 projectors, 153 small media players, 41 large media servers, 95 computers (mostly PCs) running interactives or control systems of some sort, and 165 monitors ranging between 22" and 90" (some 1080p, some 4K). There are some 14 projector blends, the largest being the 17-projector array in the Cultural Expressions Gallery.

The lighting system, an ETC Unison Paradigm with Mosaic show controller controls 33 universes of lighting ("We fought to have a single lighting control system," says Traci Klainer, CEO of Luce Group.) There are nearly 10,000 lighting fixtures and more than 750 fiber optic illuminators.

"With this much equipment, every morning something is going to need adjustment," Rey says. "Currently, we are there seven days a week, though in the future it might be less. The building is 95% automatic, but the last 5% takes my team the morning to get things running."

They approach their morning's work by walking through the building as if they were visitors. "We divide the museum up and get it running as quickly as possible," Rey says. "We put in temporary fixes if needed, get the dust out of things. I carry a small bag with remotes, screwdrivers, Allen wrenches, and a MacBook Air. On an average day, I log about 7.5 miles on foot."

History Galleries

Exhibits are organized chronologically and thematically. Visitors enter Heritage Hall at the ground level from either the National Mall or Constitution Avenue. An orientation theatre on this floor runs a show every 90 minutes.

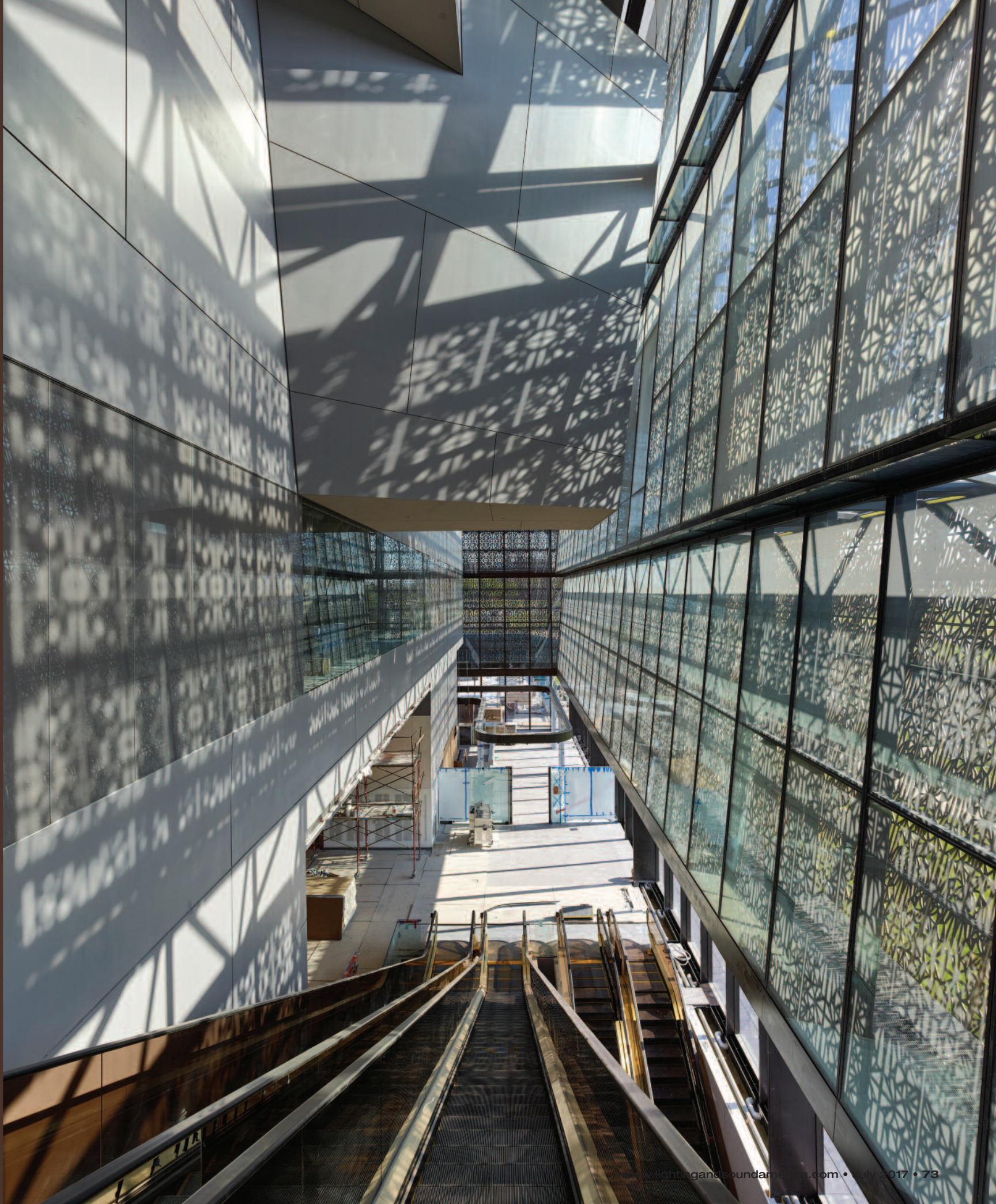
Visitors descend to the main concourse leading to the three below-grade levels. Audio, produced by Cortina, plays during the elevator ride, taking one back in time and setting visitors up for the experience that begins at the lowest level. Emerging into a low-ceilinged, low-lit area, they begin their explorations with the exhibit titled *Slavery and Freedom (1400 – 1877)*, then ascend to *The Era of Segregation (1877 – 1968)*, and finally to *A Changing America (1968 and Beyond)*. As visitors move forward in time, they also move upwards via a series of ramps back to the main concourse level.

The History Galleries play with scale. Some areas are low-ceilinged and symbolically confining; others open up and out, with high ceilings, wide sightlines, and natural light filtering in from the upper floors. Making the utmost of the combined height of the three concourse layers is a signature feature: the 50' x 250' Founding of America Wall, a complex display that tapped the full creative, technical, and collaborative powers of the team. It uses projections of large, still images combined with lighting, audio, and relief text to chronicle the sweep of history covered in the galleries (more on this below). Several of the museum's largest artifacts—a slave cabin, a log house, an airplane used by World War II's famed Tuskegee airmen, a prison guard tower from Louisiana State Penitentiary (aka Angola), and a segregated rail car—are also found in the history galleries.

RAA joined the project while the building was still in the schematic design phase, influencing the client to excavate deeper—about three times deeper—than originally planned, to configure the history cluster in this dramatic way, "once we understood the magnitude of the story and the history that needed to be told—the immensity of it," says Melanie Ide, of RAA. In her role as project director, Ide led a multidisciplinary team that included architects, designers, content and media developers, and technical consultants, ultimately totaling 85 people over the course of the six-year project.

Revising the plan for the history galleries in this way put

Photos: Alan Karchmer/NMAAHC



The Cultural Expressions Gallery is dominated by a surround that requires 17 projectors.

about 60% of the museum construction below ground. "This created the large volume and the ramping system that let us tell the continuous history story, set up the monumental [Founding of America Wall] and make a place for the large-scale pieces."

Two features found regularly along the way are designed to help visitors process information as they pass through this large facility. Reflection booths are set up for visitors to video-record their own thoughts and stories. More than 24,000 recordings have been made so far. Curators review these, and some are shared on the NMAAHC website. Landing theatres recap the exhibit content of each floor. Each has benches that seat 60 – 75, plus standing room.

Luce and LED

The Luce Group lighting design team, led by CEO Klainer and CCO Richard T. Chamblin III, interfaced with D&P systems integration specialist Matt Swerdzewski. "Creating continuity throughout the museum while also having points of interest and visual diversity was a challenge," Klainer says. "Our team took a great deal of time and effort, looking at all aspects of the design, including different fixture choices, color temperature, and where it was appropriate to add color, texture, and/or movement to support the storytelling."

Luce was brought in at the concept stage and collaborated with the exhibition design team for five-and-a half-years. The team strove to keep the number of manufacturers relatively small, for reasons of simplicity and efficiency. LED fixtures were used throughout the exhibits, including Luxam fiber optics and LSI track and track fixtures (SSLGR, 2044, 2045, BP LED, and LP3). The equipment list also features several ETC products, including the Source Four Mini, Desire D40, and Source Four LED Studio HD ellipsoidal.

(The base building lighting, done by Fisher Marantz Stone and detailed below, uses a combination of LED and fluorescents.)

"I believe this is the first museum of this size that is all LED [for the exhibits], as well as the first application of fiber-fed LED on this scale," Klainer says. "It was important to the Smithsonian and the exhibit team to be energy-efficient and have low-maintenance lighting solutions while always enhancing the collection. Using fiber optics with LED illuminators gave us the ability to have very specific focus and control—no heat, no UV. And I got to light Harriet Tubman's shawl!"

Individually controlled Rosco LitePads are also extensively for the exhibit panels, especially in the 1960s-era

Photos: Alan Karchmer/NMAAHC

exhibit in the history galleries and the Musical Crossroads Gallery. “We used backlit panels a great deal in the low ceiling areas to avoid visitors shadowing text and help give focus points. In Musical Crossroads, we chose this application to enhance and support the exhibit design.”

A custom modification of the LSI SSLGR16 fixture emerged for this project. “We originally were modifying the incandescent version of that fixture, the GR16,” Chamblin says. “To make the fixture more compatible with the Soraa LED MR16 bulb and Snap accessories, we worked with LSI to extend the glare shield on the back of the fixture as well as extending the snoot accessory to control flare. We also worked with LSI on the gasketing of the fixture so that we could more easily rotate the magnetic Snap accessories. Another modification involved changing the standard GU5.4 socket to a GU10. A notable issue with any traditional MR16 fixture is that the socket can, at times, slip off the GU5.4 (bi-pin) base. By replacing it with the GU10 base, the socket can ‘lock’ onto the bulb and is more secure.”

Manufacturers represented in the lighting equipment inventory of NMAAHC exhibitions include Acclaim, Altman Lighting, Chauvet Professional, Chroma-Q, City Theatrical, ETC, FLOS, GE, Icotek, iGuzzini, Jesco, Kings Chandelier Company, LSI, Philips Color Kinetics, Powerwerx, Rosco,

Sports: Leveling the Playing Field explores the contributions of athletes on and off the field.

and Soraa.

Manufacturers represented in the AV equipment inventory of NMAAHC exhibitions 3M, 7th Sense, Acoustic Enhancements, APC, Apple, Audinate, Audio-Technica,

The Community Galleries.

Aura, Bag End, Barco, BDA , Black Box, Boss Tab, Brightsign, Chatsworth, Chief, Christie, Cisco, Corning, Dakota Audio, Dell, Extron, Glass Apps, Innovox, Logitech, Marshall, Microsoft, Middle Atlantic, NEC, Perl, Planar, PQ Labs, QSC, Raritan, RDL, Renkus-Heinz, Roku, Rolls, Samsung, Tannot, Tripp Lite, and VDO360.

Founding of America Wall

The 50' x 250' surface of the Founding of America Wall features a collection of quotes displayed in relief text, increasing in size from the bottom up, topped by one from Langston Hughes. There are also embedded display cases with white text on glass and projection on its surface of Pyrock, a spray-on material selected both for aesthetics and acoustics.

For Luce Group, the wall represented a huge lighting challenge. “I didn’t sleep for three years,” Klainer says. “During all stages of construction, I would lay against the wall and think about how the lighting would look on this huge architectural element. Many mock-ups were done. Shadows cast by the raised letters were a challenge. We decided to light the wall like a theatrical cyclorama, using tunable white LED striplights. To counteract the shadows of letters, we used ETC LED Source Fours for front light.”

LED fixtures help keep lighting maintenance to a minimum, which is particularly welcome in an area with a 250' ceiling and no catwalk. A crew member changing a bulb will operate akin to a window washer, using a trolley on a lift on two winches to get up and across.

The mock-ups helped gauge lighting and projection on

There are nearly 10,000 lighting fixtures and more than 750 fiber optic illuminators in the museum, controlled by an ETC Unison Paradigm system with Mosaic show controller, handling 33 universes.

the various surfaces, including the Pyrock, which being irregular and porous, posed special projection challenges. "There is no place in New York or LA with that much porous rock, so the mock-up was done at RAA," says Yiannis Cabolis, chief engineer at Electrosonic. "I was there with hardware and projectors and materials, Luce was there to emulate lighting conditions." Electrosonic was hired by RAA to participate throughout the project's design phase, from concept stages to the creation of RFP documents for installation bids. "An uneven surface like that creates its own shadows," Cabolis says. "Light travels in a straight line. Projections—especially the archival images—can lose detail in the shadowing effect. The mock-ups helped demonstrate these challenges to the design teams so they could make the best possible selections."

"It's a hall that most other Smithsonian museums could fit inside," says Will Todd, of D&P, which did the AV installation. "There was a lot to work with—the three-story projection had to take into account maintenance, accessibility, and practicality. It uses eight Christie projectors in a 2 x 2 blend, double-stacked for brightness." Media content was produced by Cortina.

With the selection of Pyrock, "this wall gave us the opportunity to get acoustic control throughout the height," says Steve Haas, of SH Acoustics. "We knew we couldn't just rely on a ceiling treatment. This is probably one of the most architecturally featured applications of Pyrock ever done. The texture and coloration were precisely done to enhance the character of the gallery, and the durability is there as well. The roughness was very important, to mirror the history being portrayed. I think everybody is extremely happy about the way it worked."

AV equipment for the Founding of America Wall includes one 7thSense Delta Infinity II L 4 1800 G server, eight Christie HD14K-M projectors, 11 Christie stacking frames, four Extron 60-1060 21 FOXBOX Rx DVI Plus MM multimode receivers, four Extron DVI DA4 Plus distribution amplifiers, four Extron PowerCage Fox Tx DVI Plus MM multimode transmitters, eight Perle 5050424 10/100 media converters, and eight Perle Fast Ethernet media converter modules.

The Lunch Counter, Green Book, and other interactives

The Lunch Counter in the second History Gallery is emblematic of how interactive exhibits can function simultaneously on the individual and group scales, and as entertainment and education. Users sit on stools at 12 individual workstations set into a countertop, evoking the landmark, nonviolent civil rights protests that took place at lunch counters in the 1960s.

The workstation area is surrounded by content on big screens that create contextual environment. "It's a communal area with layers of content," says Joe Cortina, president and creative director of Cortina Productions, whose team collaborated closely with RAA on this feature. "You can stand and watch the film while others are doing the interactive, and you can look over your friend's shoulder while they are engaged in the interactive, you can take it all in from a number of vantage points."

Programming for this interactive includes a special mode for teachers and school groups. The results can be saved and used back in classrooms for further discussion.

From here, the visitor path continues to three upper floors: Explore More!, Community, and Culture. Each floor has an open, central display area surrounded by smaller, themed galleries. There is media throughout the museum, and the way it is incorporated becomes more modern as the content itself becomes more modern.

Explore More! features interactive exhibits sponsored by corporate donors. It is family- and school group-oriented and includes classroom space and a library.

The American Alliance of Museums (AAM) honored NMAAHC in 2017 with a Gold MUSE Award in the interactive kiosk category, for the interactive car exhibit, *Follow the* Green Book, in the Target Learning Center on the Explore More! floor. The *Green Book* was an annual guide written for African-Americans to help them find businesses and accommodations where they would be welcome while on the road, in segregated, 1930s – 1960s America.

A 1949 Buick was cut in half and modified for the display, with the windshield serving as a projection surface, and three Planar Mosaic screens and a PQ Labs IR frame touch sensor in front of the dashboard. On a simulated trip from Chicago to Alabama, the user makes selections about where to stop along the way and sees the results projected on the windshield. Cortina collaborated with exhibit curator Katy Kendrick, exhibition designer Mike Biddle, and D&P.

Two other Cortina interactives: One teaches a "stepping" dance routine developed in African-American colleges and fraternities. It is part of Explore More! The other is a large table interactive in The Power of Place Gallery, which is featured in a well-known photo showing President Obama and his family engaged with it.

Also in Explore More! is The Ark, an interactive wall, produced by Cortina, that allows visitors to digitally explore virtually all artifacts in the museum.

Cortina's team collaborated closely with the Smithsonian IT department as well as D&P's IT team on content management systems (CMS) for the interactive exhibits. "Alison Wilcox and her IT team wrote back-end CMS code for all the interactives, and we wrote front-end CMS code to tap into theirs," Cortina says. "D&P was the systems integrator so we worked with them not only for actual exhibit hardware the visitors would use, but also the firewalls and various other technical aspects."

Equipment for the interactive Lunch Counter includes one 7th Sense Delta media server, four Barco F32 projectors, four Extron 60 1060 21 FOXBOX Rx DVI Plus MM multimode receivers, four Extron 70 873 11 PowerCage FOX Tx DVI Plus MM Multimode Transmitters, eight Innovox SHA loudspeakers, four Perle 5050424 10/100 media converters, four Perle Fast Ethernet media module cards, and four Tannoy VX 8.2 dual 8" loudspeakers.

Interactive Lunch Counter equipment includes 12 3M stackable LCD screens, two Perle 5050424 10/100 receivers, two Perle 05051420 Fast Ethernet media converter modules, and two Audinate Virtual Soundcards.

Community and culture

One floor above Explore More! are galleries focusing on community, comprised of four exhibitions: *Making a Way Out of No Way*, *Sports: Leveling the Playing Field*, *Double V: The African American Military Experience*, and *The Power of Place*. The museum's top floor looks at culture in four galleries: Visual Arts, Musical Crossroads, and Taking the Stage, all surrounding the signature, central Cultural Expressions Gallery with its 17-projector surround.

The 17 projectors and screens are aimed at an elliptical screen overhead, above a ring of display cases and benches. The eight-minute film, which complements the content of the nearby galleries, was produced by Cortina for the custom format. "The 17 projectors are edge-blended for the compound curve of the projection surface, which is not only oval, but with a different radius at the top than the bottom," Cortina says. "We made a 26000 x 1080 film, knowing the total number of pixels to work with was between 26,000 and 27,000."

"When we were commissioned, the design of the 360

Photos: Alan Karchmer/NMAAHC

A series of Rosco LitePads are used in this gallery, which looks at the tumultuous events of the 1960s.

screen itself was complete, and we worked closely with the curator on content," Cortina says. "D&P provided us with a pixel map of what we were going to build so that we could test it. For final production, we used After Effects, which has a 30,000-pixel limit, so we were pushing the boundaries. Our production team created the film at 29,000 pixels, knowing that edge-blending would bring the count down.

"There used to be a pretty clear delineation between media design and exhibit design," Cortina says. "Now they are completely integrated, and that goes for mobile and social media as well; all of it is melded into experience design." Software tools Cortina used for the various pieces of media created for NMAAHC include Adobe CC 2017, Unity, HTML5, .NET, Microsoft Kinect, 3D Studio Max, Cinema 4D/Phoenix, and Maya.

Cortina praises SH Acoustics' audio work in this space. The volume needed to be audible, but not overpowering, wherever visitors are in the space, seated or standing, whether focused on this film or moving around, browsing the display cases. SH Acoustics addressed this by placing transducers in the benches, where they function as speakers. "You can hear it and feel it," Cortina says. "It's not outright shaking, just reinforcement of sound at close proximity, without significantly raising the overall volume in the room. It works well, mixed with the speakers up at screen level."

"The media displays on a continuous perforated screen that wraps around the entire room, up high," Haas says. "To make the stereo audio feel multidimensional, we placed six Renkus-Heinz ICONYX IC16-R-IIs behind this elliptical screen. We used ray tracing to derive the optimal spacing for good overlap. The exhibit designers placed interactive stations right under the screens, facing the outside of the ellipse. So we had to ensure the Iconyx weren't in line with the interactive exhibits. Otherwise, the speakers' vertical spread would pummel sound down on top of the interactive stations. Once we knew where the interactive stations would be, we figured out how to shift and weave the loudspeakers so they created an immersive overlap. Each array provides specific area coverage. We created enough of an overlap that we get even coverage,

Photos: Aki Carpenter, RAA

yet it feels like some sounds are close and some are distant."

SH designed the sound for these and other exhibit videos in stereo, rather than surround, because the gallery theatres are so open. "We used tricks with delayed stereo to achieve immersive environments without leaking to larger areas," Haas says. "Renkus-Heinz Iconyx IC8-R-II and IC16-R-II loudspeakers were our choice for front program speakers because we could use their beam-steering technologies to precisely place audio with minimal leakage between exhibits and spaces. We used them in unique ways. Sometimes we had to turn an IC16 on end to be horizontal instead of vertical, letting sound bleed up and down. The beam steering technology comes in very handy where you can't use position to get right in the middle of that line-array focus. The speakers can be placed high up and you can steer the beam down into the people zone."

Luce lit the Cultural Expressions area using ETC Source Four Minis with shutters. Outside the ring, lower down, Luce used iGuzzini fixtures. "We expanded our kit here as this was what could do the job," Klainer says. "The Iguzzini lights are architectural fixtures that can go nearly flush, or you can pull them out and angle them." In adjoining gallery areas devoted to theatre and performing arts, a range of theatrical fixtures was used, including Luxam Nano, Micro, and Mini Spots, and Luxam Lightsticks. These areas also have livelier colors than the earth tones of the history galleries. "The goal was to give the feeling of a creative space—a theatre, TV studio, movie studio," Klainer says.

The music galleries have a great deal of simultaneous sensory input, with AV, video, lighting, and unique artifacts. The P-Funk Mothership, a space vehicle designed for concerts featuring George Clinton and his band Parliament Funkadelic, "was a challenge, as it is an artifact but also needed a feeling of color, texture, and movement," Klainer says. "We used an ETC RGB LED Source Four with no lens. This gave us the texture and color we desired, while using only one light."

Other AV equipment used in the Cultural Expressions area includes a 7th Sense Delta Infinity media server, 13 Acoustic Enhancements ASP AAH CUST15 activated drivers integrated into benches, 17 Christie DHD555-GS video projectors with long-throw lens, 17 FOXBOX Rx DVI Plus MM multimode receivers, 17 Extron PowerCage FOX Tx DVI Plus MM multimode transmitters, 17 Perle 5050424 10/100 media converters, and 17 Perle Fast Ethernet media module cards.

A networked museum

"All the equipment lives on its own network," Rey says, "a secure, yet open, network, independent of the rest of the building, to let all the systems and devices talk to each other. Everything runs on fiber for signal and control—fiber is used instead of copper category cable. There are miles of conduit. The ETC Paradigm Net 3 lighting network is independent of the other networks and contains all lighting programming. The Mosaic does the fancy stuff, the moving lights and colored lights. There is a separate system for the architectural lighting that is also run by the Paradigm—both lighting control systems were merged and the Medialon Manager Pro V6.5.1 is the boss, handling basic, schedulable controls and day-to-day commands. The QSC Q-Sys [audio, video, and control system] feeds and controls all the audio. There is APC battery backup for power fluctuations. Dell switches communicate from room to room over fiber and inside each control room via CAT 6 (for lighting)."

The system is programmed to turn itself on and off, using Medialon Medialon Manager. (There are five, one for each exhibit space.) "We are still putting some finishing touches on the scheduler," Rey says.

Klainer says that The Founding of America Wall presented the biggest lighting challenge of the entire project.

Building vibrations make it necessary to re-align the Cultural Expressions projectors every two weeks or so, using alignment software built into the 7th Sense servers.

Like other Smithsonian museums, NMAAHC depends on LSI lighting track, and 3M monitors. "In a pinch, I could run across the street and borrow from a sister museum," Rey says. "Many of us have worked in more than one Smithsonian building in our careers, and we have gotten in the habit of sharing skills and equipment. There's a guy at the National Portrait Gallery who is really good at programming Medialon, for instance. It is quite a college campus kind of thing."

The QSC networked audio system runs a Dante audio

network, with all the audio feeding over a separate IP network. "Via Medialon, the QSC audio faders can be adjusted by a single decibel, so it is pretty fine-tuned," Rey says. "I can mute a section, or the whole building. If I go into Q-Sys I can equalize, crossfade, and change channels. I can do it from home or onsite—everyone on my staff has a VPN account."

Refreshing the media content is straightforward. "I upload it to the server and tell it to play," Rey says. "Interactives are updatable through the in-house CMS."

Concourse C of the History Galleries looks at the slave trade and the Revolutionary and Civil Wars.

AV design

Electrosonic was hired by RAA to participate throughout the project's design phase, from concept stages to creation of RFP documents for installation bids.

"Many technical challenges had to be realized, and many extremely complex projection studies done, for more than 220 multimedia exhibits that span a very wide timetable, with media ranging from archival footage to relatively new productions," Cabolis says. "All those galleries require space, but so does the equipment [there are five electronic equipment rooms, or EERs, in the museum]. It was a balancing act of budget and infrastructure, the needs of the design team, and the long distances the signals had to run on a very elaborate and extensive fiber infrastructure."

"You never want AV to overpower; it's a fine balance between telling stories and reliable infrastructure to present the content," says Ben Allwag, Electrosonic design consultant. "It was an exacting process."

"Many exhibits have multiple speakers, each with its own separate channel of audio to process—anywhere from two to 12 channels—with no time delay or echo," Cabolis says.

The final documents Electrosonic delivered for bid specifications "consisted of drawings that identified all of the facility in terms of the connectivity expected between EERs and the devices being served, the way the technology was to be deployed, and also the topology—as well as quantities, make, and model of devices expected to be used," Cabolis says. "We asked to approve all substitutions. In addition, we provided detailed projection studies, identifying equipment make, lens type, model, where it would be located, the number of pixels each projector would be projecting on its particular surface, and the projection angles for every single exhibit.

"The discussions were not just about projection, but also on the server side, taking into account work flow and what the content producer would be doing. These were delivered as 3-D AutoCAD models to RAA. We internally resolved those models using a combination of tools, principally SolidWorks and StudioMax. We have proprietary plug-ins on StudioMax to identify cross-reflection on curved and angled screens, taking into account lighting conditions."

SH Acoustics: all things soundwise

As were Luce and Electrosonic, SH Acoustics (SHA), headed by Steve Haas, was brought in by Appelbaum in early design stages. "We were responsible for all things soundwise: the acoustics of exhibits, galleries, audio delivery design, and calibration," Haas says. "That included handling all the loudspeaker and other device selection—quantities, configuration, and mountings—that got folded into AV design. We also oversaw installation and were on-

Certain artifacts, such as the cabin, above, are so large that they had to be installed before the building was completed.

site to do the final calibration. Our role also included interfacing with media producers to make sure their content would coordinate well and to suggest any necessary adjustments prior to delivery of the media."

The SHA team set criteria for the architect and base building team in regard to acoustic quality treatment and sound containment in galleries.

According to Haas, modeling with various programs is helpful, but less effective than for a concert hall or recording studio because of the way the space is divided. "The most important part is understanding it's a 3-D puzzle to solve. You can't think of it floor-to-floor—it is subdivided but also very open. We had to be very aware of how sound would travel laterally, and also up and down in some cases, with the potential to impact other exhibits."

Some challenges couldn't be anticipated, such as museum docents bringing their own portable mic systems. Also, during the final weeks and months of production, the museum became a favorite place for President Obama to stage interviews, and many VIPs were brought in for advance previews. Everyone was obliged to suspend work and clear out at such times. "There was no hiding out from the Secret Service to get in just a few more minutes of DSP programming," Haas says.

SHA played a role in shaping the entire audio delivery system, and the QSC Q-Sys tool was essential. "The backbone of our work is with DSP, making sure we have all the tools and functionalities to do calibration and do it effectively," Haas says. "Q-Sys is our go-to DSP, and one of the best options the Q-Sys platform provides is the backbone for calibration and distribution of devices, speakers, and transducers."

Haas favors audio delivery devices "with a unique form factor that can be readily concealed while preserving sound quality, whether to localize sound or spread it." At NMAAHC, these included panelized versions of transducers, and 2" customized Innovox speakers, located beneath walkable, historic-looking gratings and in the backs of benches.

Haas relied extensively on Renkus-Heinz Iconyx loudspeakers for the exhibit spaces. "There are media programs of all types, from large-scale to hundreds of interactive exhibits, smaller experiences, touch screens, and soundscapes," he says. "The spaces are enormous, and we had to control sound in many overlapping areas. The Iconyx speakers gave us the beam-steering technology and high-end audio quality we needed."

SHA also used Dakota Audio speakers focused in a variety of ways, "sometimes overlaid to support accented programs within a soundscape that filled galleries lightly, creating immersiveness without interfering with individual programs."

Photos: Aki Carpenter, RAA

Installation: Design & Production

Design & Production won the bid to build, fabricate, and install and was contracted directly to NMAAHC. The D&P team, headed by senior project manager Debbie Cone, included senior vice president L. Sue Lepp, senior engineer Will Todd, vice president of operations Michael Lockard, project engineer David Davis, and graphic director Barbara Rayder.

"A lot of the sequence of production is in the planning," Todd says. "Almost a year before entering the building, we had an 80% complete view of how everything was going to unfold, based on experience. We looked at all trades and all design documents and laid it out in meetings to arrive at a clear view; then we started scheduling, building, and fabrication."

The process took a little less than two years. Typically, the very first thing, Todd says, is to work with the general contractor. "We get together with them early on, pre-slab, to lay out pipings and confirm pipe. In terms of the placement of infrastructure, some places have a little wiggle room and some have to be dead-on. For the latter, we fabricate templates and then lay them out so the GC can have their trades put it exactly where it goes. We have the ability to take their CAD drawing and ours and sit them on top of each other to spot issues early—it's huge to be able to do that now."

Once things are finalized with the GC, the process moves from consultation to installation. "Luce and SH Acoustics were both involved every step of the way," Todd says. Of the museum's internal team, he interacted mostly with Chase and Sieling: "When you have a client in the room with you, sleeves rolled up, it's the best thing in the world. It's a 'we gotta get this figured out' partnership. The Smithsonian is very aware of the next generation, who their clientele is, and the educational message they want to convey. How we did things 20 years ago versus how we do them now is like night and day, and that's awesome—it means more 'toys' for me."

Mona Electric Group, Inc., electrical contractor for the exhibit space, installed the AV cabling, as laid out by D&P, along with all exhibit electrical, lighting track, and exhibit low voltage/fiber wiring. This was spearheaded by Dave Davis at D&P.

Todd says, "Our people were in the shop, fabricating control racks, exhibit cases, and pre-staging so we could start laying all these things as the spaces became available to us. Once we were cleared to be in the space, we would bring in larger things and lay stuff out, the racks went in, and our field team started putting in the AV gear, bouncing around to different places. In relation to what's going on in the museum and the amount of AV, the control rooms are tiny—but we still have 16 racks in there!"

It took about a year before the spaces became dust-free, with major fabrication complete. At that point, the team began to add projectors, monitors, and other sensitive components where the mounts had already been put in. "Then, we could knock out a whole hall at once," Todd says, "after which specialists would come in, such as Mike Donaldson, to program the Medialon, and Jonathan Bailey, to finish the physical projection layout, program for blends and do other finish work."

Architectural lighting: Fisher Marantz Stone

The Fisher Marantz Stone architectural lighting team included Carla Ross Allen, LEED AP ID+C, associate, as project manager, with senior associate principal Hank Forrest, and president Charles G. Stone II. They were on the project for eight years, beginning in 2008.

"We collaborated with Adjaye Associates [building design lead]," Ross Allen says, "to integrate architectural lighting elements to illuminate and brighten the large, interior, cavernous space during the day, while creating an elegant, exterior presence at night."

For interior spaces, USAI downlights were the primary fixtures of choice. "We needed a small aperture fixture, with a nice cutoff, great beam, and availability in a large variety of options."

Working with the building's complicated façade, a sandwich of dark metallic panels and curtain wall, FMS sought a solution that would allow the building mass to appear lively and transparent. To achieve this, FMS located linear fluorescent fixtures from Winona Lighting at the top of each corona tier. "The linear fixtures illuminated the building's exterior glass panels—which were treated with a frit pattern—allowing for a lightable surface that silhouetted and revealed the nature of the exterior metal panels," Ross Allen says.

FMS also lit the interior of the Oprah Winfrey Theater, which echoes the bronze lattice work of the building exterior. "The panels in the theatre are described as an inverted corona," Ross Allen says. "FMS integrated linear LED fixtures within each panel tier, creating a warm, dark space echoing the exterior lighting effect.

"In order to satisfy various agencies responsible for Washington DC's Monumental Core District, FMS surveyed the site, as well as the mall, looking to understand the evening presence of the existing buildings and features on the mall," Ross Allen says. "Additionally, throughout our design process we completed in-house mock-ups, and participated in full-scale lighting mock-ups. While our goal is always to complement the building with lighting, we were also conscious of the project's green building objectives, and worked hard to balance the magic of lighting with the project-directed sustainability goals."

Much of the base building control system was tied into the ETC Paradigm, driven by the needs of exhibition design. However, FMS specified a Lutron Grafik 6000 sys-

Photos: Alan Karchmer/NMAAHC

The exhibition titled *Making a Way Out of No Way* features themed stories showing how African Americans crafted possibilities in a world that denied them opportunities.

tem, used in the following spaces: Oprah Winfrey Theater, Contemplative Court, main hall (ground floor), multi-purpose rooms, patron lounge, boardroom, and VIP room.

Installation was managed by Clarke Construction and Mona Electric, with FMS remaining on-site as a guiding voice from construction through installation. FMS and Luce Group worked together from early stages for coordination of control and manufacturers, ensuring all track in the building was consistent (all LSI track).

Software used for the project by the FMS team included Adobe Creative Suite, Autodesk Revit, Autodesk AutoCAD, and Lighting Analysis AGI.

What it's all about

"They gave us four walls and we gave them a museum," Todd says.

"The best buildings tend to be those where the exhibits are developed alongside the architecture, and the spaces in the building take on the context of the exhibits," Haas says. "That happened here."

"Our rich background in historical exhibits helped give us perspective for the challenge of NMAAHC—to ensure the technology functions as a platform for the curators to populate and immerse the guests in content," Cabolis says.

"I used everything I learned throughout my career—lighting museums, theatre, themed entertainment," Klainer says. "It was life-changing for me and I believe it is life-changing for the visitors."

"To make something this monumental happen—to create a world-class museum—called for a world-class team of experts in their respective fields," Sieling says. "We were lucky to have everyone's 'A' team on this project—from planning and design to engineering, fabrication, and installation—it all came together beautifully to create a seamless, moving, and memorable experience for our visitors. At the end of the day, that is what it's all about."

The Oprah Winfrey Theater

The Oprah Winfrey Theater at NMAAHC is located below ground, opening directly into Concourse C of the History Galleries. The main theatre entrance is off the main lobby, down a great circular steel staircase.

The 355-seat theatre was designed to support a broad range of uses. According to Keith Madden, the theatre director, the possibilities include events, symposia, curator talks, conferences, corporate meetings and presentations, awards ceremonies, live theatrical performances, dance, live music (from jazz to string ensembles), feature films, documentaries, archival media in a variety of formats, and other special programming. The theatre also functions as a recording and broadcast location. There are many tie-ins with exhibition content and mission-relevant material and with the Smithsonian Channel.

Naturally, the Oprah Winfrey Theater hosted many NMAAHC opening day festivities, concerts, and lectures. Peter Rosenbaum, who headed the team for theatre consultant Fisher Dachs Associates, notes that the venue was prioritized for early completion, in order to be ready for these.

Aesthetically, the theatre interior echoes architectural themes that characterize the rest of the building, with panels utilizing the decorative corona motif. “It’s a jewel box of a space,” Rosenbaum says.

“People kind of gasp when they walk in,” Madden says, who has been on staff at multiple Smithsonian museums since 1996. “It’s not ostentatious, just gorgeous.”

Shen Milsom & Wilke, LLC (SM&W) was the acoustician on the project. The ETC theatrical lighting system was installed by Barbizon Lighting, and the rigging was installed by SECOA, per Fisher Dachs specifications. Clarke Construction subsidiary S2N was charged with implementing the AV install.

In and out of the booth

The theatre has a proscenium stage; it and the auditorium are 50' wide; the stage is about 23' deep and the room 90' long, with ceiling height ranging 23' – 27'. (Harlequin Floors supplied Cascade Marley floor in black for dance performances.) There is a small backstage corridor for talent and stage management, equipped with video and audio outputs and monitors, company switch, and lighting panels. Also backstage are two storage closets and four green rooms and dressing rooms, connected by a Clear-Com communications system. The back-of-house area connects directly to the building’s loading dock.

The AV design has gone through some stages. Madden, who came onboard in August 2016 while construction was still underway, helped steer equipment decisions to support the desired range of capabilities. The theatre is set up for Dolby 5.1 cinema audio and 35mm and 16mm film, as well as DCI-compliant digital cinema projection. The equipment supports video switching, camera control, recording, and webcast.

In August 2017, a new, retractable Stewart SnoMatte 36'-wide perforated cinema screen was rigged further downstage to accommodate new cinema audio amplifiers and speaker arrays behind the screen. Equipped with quick disconnects, these four-way speaker arrays with QSC mid, high, and very high horns and a pair of JBL pattern control bass cabinets for left-center-right channels are each mounted to Genie Lift carts. “They can be wheeled on- and offstage as needed and raised to the proper height for optimal cinema sound coverage,” Madden says. A manually operated side masking system was also rigged and installed in front of the screen, to allow clean masking for all projection formats, along with an upstage heavy fabric traveler that closes behind the cinema speakers to provide a light and sound baffle. “This new system provides a world-class cinema experience and supplements the live sound and PA system,” Madden says.

At mezzanine level is the three-room booth, with one room dedicated to lighting and video production, one to projection, and one to audio. In the first room lives an ETC Ion lighting control console. In the middle room are a Christie 4K digital cinema projector and two Kinoton FP 38-E film projectors. These top-of-the-line Kinoton products are no longer manufactured and were acquired used. “They run actual film,” Madden says—whose experience includes years as an IMAX projectionist and certified service technician—“including 35/16 archival prints, reel-to-reel, and most other film formats, including 70mm. The ‘E’ stands for electronic; the projector uses a servo motor and controller to precisely pull down the film, giving a very steady image and allowing adjustment to any frame rate,

The theatre is designed to handle a broad array of events.

easily. Film is coming back." Madden, who also worked on the recent 70mm feature film releases of *The Hateful Eight* and *Dunkirk*, also provides his services as an install technician, technical representative, and often projectionist to the Sundance Film Festival, CinemaCon, Turner Classic Movies Festival, AFI, Toronto International Film Festival, and Tribeca Film Festival, among others.

In the third room of the booth, audio racks and control include a Midas Pro 2 audio console. All processing is by Biamp. "It can be stand-alone or switch to sound console; turn on your mic and the Biamp just kicks in, with auto mixing capability," Madden says. "Up here in a soundproof booth is not the best place for a sound console during live events, so we bring it down to the middle of the house and set it up on a table in one of two live mixing positions. We recently added a digitally addressable Midas DL252 stage box that we can wheel around, and get 64 channels of audio in and 16 out."

There are four Panasonic remote-control studio cameras with tilt/zoom, motorized heads controllable from the booth. A Grass Valley digital recorder/player can play back digital video files and uncompressed video. Also featured is a broadcast-style Ross crossover video switcher.

Renkus-Heinz short-throw and long-throw speakers and subwoofers, plus JBL surround speakers, are positioned in a left-center-right formation in the ceiling of the proscenium, delivering sound through openings in the drywall on the steel-beam structure, hidden behind black fabric and four flat acoustic clouds angled down toward the audience. "The design was for an acoustically transparent

Photos: Alan Karchmer/NMAAHC

The architect specified a silver palette for the theatre's interior; the customized seats are by Series Seating.

auditorium, with the long-throw reaching most of the house and the short-throw covering the first few rows," Madden says. This system was augmented recently as described above.

In addition to Rosenbaum, the Fisher Dachs team included theatrical lighting designer Jon Sivell, and rigging designers Joe Mobilia and Scott Madaski. Their scope covered planning and design of the theatre, back-of-house spaces, seating and sightlines, rigging, lighting, stage machinery, and variable acoustics. They interfaced with the NMAAHC architectural team to ensure the functionality of the spaces, as well as the AV and acoustics specialists.

Fisher Dachs design tools included a proprietary software package to establish and optimize seating and sightline layouts for the theatre's range of uses within the constraints of the architecture. "One of the great challenges of being underground was that we had to meet certain building elevations and study the relationships between the various floor levels to create appropriate sightlines for the range of activities, to maximize the audience experience and make the room feel intimate no matter what was going on—dance, music, film, theatre, or lectures," Rosenbaum says.

Lighting, rigging, and control

The theatrical lighting package for the Oprah Winfrey Theater includes 192 circuits of ETC Sensor dimmers and 48 SmartSwitch relay circuits for theatrical lighting, ETC Unison 277V dimming for architectural lighting with Paradigm controls, and an ETC Ion 2000 theatrical control

Photos: Alan Karchmer/NMAAHC

console with fader wing, RVI, and RFR remote and custom ETC faceplates for power and data distribution.

The fixture inventory consists of 112 ETC Source Fours in various models and degree sizes, five Philips Vari-Lite VL1100TSD units, along with assorted fixture accessories and hardware from City Theatrical and cable inventory from Lex Products.

Ten self-climbing hoists (four front-of-house electrics, five onstage electrics, and one cyc batten), engineered, and supplied by SECOA, take the place of a traditional lighting grid. The system employs triangular trusses about 50' long, with 12" sides. Motors inside the trusses connect to a rotating line shaft. The truss lifts itself up and down via integral cables on winches. "There is no need to set up a ladder to get to the lighting equipment—it comes to you rather than you going to it, allowing for staff to quickly and easily maintain all the lighting within the theatre," Rosenbaum says. "These motorized lighting battens are able to reach across the entire audience seating area and allow staff to quickly and easily maintain all the lighting within the theatre without resorting to ladders. It's a relatively new approach that has proven very successful in dealing with overhead lighting. Rather than a stage tower, there is a stage loft that has all the rigging overhead. There is also a series of dead-hung pipe across the stage for general purpose use. The rigging control system is interconnected to the house lighting and AV control so the variable acoustics banners can be raised and lowered from the booth."

Sparkle in the room

As the architect wanted a silver-themed palette throughout the room, the Fisher Dachs team mocked up the house curtain as a translucent fabric of metal threads (Rose Brand Duet fabric in the color Steel). The initial design had the curtain rise into the ceiling to be concealed there. Ultimately, there was less clear height above the stage than anticipated; in addition, the curtain had to be backed with more layers of fabric, which resulted in a deeper curtain stack than originally planned. Rather than disappear entirely, when retracted the curtain forms a valance across the entire room, a serendipitous result that harmonizes pleasingly with the silver corona panels.

The architect also wanted silver highlights in the seating. "We spent quite a bit of time designing these customized chairs made by Series Seating," Rosenbaum says. "We went through many iterations to combine fabric and silver laminates for just the right amount of sparkle in the room." The room meets code for wheelchair access and has six wheelchair places and some with removable seats up front, and at the cross-aisle.

Acoustics

Motorized battens of sound-absorptive material (wool fabric banners made by acouStaCorp) live inside the back and side theatre walls and can be raised and lowered to tune the room using established presets or as needed. Fisher Dachs designed the system in accordance with performance criteria that SM&W provided.

"The reverberation time for speech intelligibility—for instance, to show a movie—is diametrically opposed to what you need for a concert," says Julie E. Fischer INCE, LEED AP BD+C, associate principal, Shen Milsom & Wilke. "The hidden curtains in the walls lower down and raise up to adjust it. We did quite a bit of testing to determine how the curtains would be affected inside the walls, behind the ornate screens. The screens are backed by a speaker cloth material that allows sound to pass through. Behind the acoustic curtains is diffusive CMU [concrete masonry unit], which is used to break up sound—it allows a longer reverb time while breaking up echoes, which is good for symphonic music. In general, you build for long reverberation and then adjust for short reverberation."

"This worked beautifully for symphonic ensembles from the US Army 'Pershing's Own,' which performed pieces from four African-American composers, and then later jazz performances, including legend Randy Weston with his quartet," Madden says.

In addition to collaborating with Fisher Dachs, Shen Milsom & Wilke interfaced with the architects, structural engineers, and mechanical engineers to fulfill its job scope. The location of the theatre in the center of the building, with MEP systems directly below and the central lobby area above, called for a box-within-a-box sound isolation system. The space was provided with a floating floor slab—a separate pour of concrete decoupled from the rest of the structure. The walls of the theatre are also completely separate. The noise above the theatre was a big concern. "If you have someone rolling a cart, or heel-click noise, or a school group running across, you don't want to hear any of that," Fischer says. The theatre's sound barrier ceiling uses multiple layers of drywall, hung on isolation hangers. As the theatre is fed with ductwork hung from the slab structure above, special care was taken with how the mechanical equipment was hung. "If it is rigidly attached, you 'short-circuit' the isolation," he adds.

Other low-noise measures include the use of sound attenuators, very large ducts, and acoustically rated doors. The control booth is separated by glass, which is angled so as not to create an echo down into the seating area; a floating floor in the projection booth keeps it quiet.

Shen Milsom & Wilke built a digital model using CATT software to test the different finish types—CMU, curtains, drywall, floor treatments, etc.—and get the desired reverberation times.—**Judith Rubin**