When it came time to implement a seismic upgrade to the historic Salt Lake Tabernacle of the Church of Jesus Christ of Latter-day Saints (LDS), a remarkable building that has weathered nearly a century and a half, it was decided to overhaul and upgrade the theatrical systems as well. The house of worship stands in Salt Lake City’s Temple Square and is the home of the Mormon Tabernacle Choir. It is also Utah’s most popular tourist destination, used daily for a variety of live events, including religious meetings and musical performances, most of which are also broadcast and recorded. Therefore, any new theatrical systems had to work for both the live audience and broadcast community.

The building’s standout architectural feature is the 150’-wide, elongated dome roof, engineered by bridge builder Henry Grow and constructed in a lattice-truss arch system. As the story goes, Brigham Young, the famed Mormon leader, didn’t want a large number of support pillars interfering with the congregation’s view. The capacious attic space within that roof turned out to be a handy area for the support infrastructure for much of the Tabernacle’s new lighting, sound, and audio equipment. The technical consultants became well acquainted with the dome in the course of their work.

“The trusses live between the domed ceiling and roof, and are quite amazing,” says S. Leonard Auerbach, whose company, Auerbach Pollock Friedlander, worked on the renovation as theatre consultant. “They’re designed as bridge trusses and are all pegged together, and have been holding up since the beginning.” The Auerbach Pollock Friedlander team included Grace Gavin on lighting systems, Dan Mei on video systems, and Tom Neville on a network of custom hoisting mechanisms and lifts.

Most of the extensive, new state-of-the-art installation remains out of sight of the people in the pews. “The complex extends far beyond what the
 visitor sees when they come to Temple Square,” notes acoustician Edward McCue, principal consultant and project manager for Kirkegaard Associates, provider of audio and acoustical consulting to the renovation. “Underground, there is a fantastic complex of not only dressing rooms and support areas for the choir, but also rehearsal rooms and media rooms for broadcast and production.” The Kirkegaard team included senior consultants Richard Laidman (audio system design), Tim Gulsrud (acoustics), and consultant Ben Willt (noise and vibration control). FFKR were the architects in charge of the project. The audio, video, and production communication systems installer was Diversified Systems Inc. Lighting equipment was supplied by Barbizon.

The interior space of the domed attic, having been structurally strengthened, helped the team to fulfill the client’s mandate to install 21st-century theatrical systems while leaving the historic architecture visually undisturbed. “There is about 10’ of space between the ceiling and the roof,” observed Auerbach Pollock Friedlander’s Tom Neville. “We used that space for mounting the equipment. Using the attic space, we were able to put 10lbs. in a five-pound bag. I have to hand it to Jacobsen Construction, the contractor; their team did a great job defining the zones in which everybody could mount their equipment. One challenge to the entire team was to ensure there was never a fire during construction. This meant that no one could weld in the space and it also meant that the sprinkler system was continually active. The new sprinkler system was completely installed and operational before the old system could be removed. One difficulty is the sprinkler system was never off—for safety reasons, we couldn’t turn the old system off until the new one was in, so no welding could be done anywhere in the space. Up in the roof, there is now the electrical system, the new ice reduction system, all the winches for the light trusses and chandeliers, the sprinkler system, and some sound stuff. It is fairly accessible by wooden ladders and work platforms.”

A considerable patchwork had built up inside the Tabernacle. “Over years of use and changing technologies, things were just attached here and there—lighting positions on balcony fronts, on the organ, behind the organ,” says Gavin. “It wasn’t integrated; it looked like it was just hanging off random supports, and everything was black and taped, as if the backstage had been brought into the audience—but a lot closer to the audience than if it were in a theatre.”

The acoustician also had to deal with decades of plaster repairs. “There were perhaps 30 coats of stuff, all different materials and paints,” says McCue. “The longevity of a plaster ceiling depends on its ability to breathe—for water vapor to pass through in both directions—and these multiple coatings were counterproductive to that.” In addition, the restored plasterwork had to preserve the space’s sound reflectivity. A tip from the other side of the Atlantic, where similar situations crop up in buildings older than the Tabernacle, led to the choice to use Keim silicate paint, a plaster refinishing material that provided the necessary qualities.

In order to accommodate the various events held in the Tabernacle, the rostrum was fitted out with modules and lifts that enable it to assume three different configurations: “orchestra,” “stake conference,” and “general authority.” Each mode has different parts and pieces that are moved from the underground storage area and up a large stage lift to the floor of the tabernacle where they are positioned. Auerbach Pollock Friedlander developed the lift system to accommodate the various uses. The transformations can be effected in 24 hours or fewer, depending upon the configuration. “It’s essentially a
very flexible concert hall,” says Auerbach. In “general authority” mode, about 100 people are seated on the rostrum. For other modes, the seating platform modules and nonessential AV elements are lowered into the storage area.

Auerbach Pollock Friedlander facilitated the design of the presentation and broadcast lighting system, and created a custom hoist system for the new lighting positions within the cavity of the dome, which was strengthened with a new steel framework.

“All winches are at the spring point of the dome,” says Auerbach. “The cables go up within the cavity to the points from which they can make their drop. This being an archway, there’s a complex deployment of cables that required plotting pathways in 3-D CAD so that the cables wouldn’t interfere with anything else.” All the overhead rigging controls are automated.

The rigging package includes a Nomad control desk from Stage Technologies handling 14 Stage Technologies Big Tow 1,000lb. BT2-390 winches (for trusses, speaker clusters, and future use), seven 750lb. BTS-290 winches (chandeliers), and three 500lb. BTS-200 winches (for clearing the organ). Other key elements include five custom trusses and two tension wire grids.

Reimagining the lighting
“LDS techs set the lighting design criteria per se,” Gavin says. “They knew what they wanted. They did the plots and we wrote the specs.” Two products the client wanted were relatively untested at the time they were specified. First was sinewave dimming, provided by ETC. “They are quieter and also more expensive than standard rise-time dimmers,” says Gavin. The system was implemented for the house lighting dimmers, where the new technology would eliminate the most lamp noise. “The theatrical lamps chosen for this project are very small-filament and less of a concern than the ‘noisier’ house chandelier fixtures,” Gavin adds. “The acoustics consultant was very keen on the use of this product for the decorative dimmed loads.”

“We were very happy about the sinewave dimmers,” concurs McCue. “That technology was maturing while we were specifying the equipment for this project. For the Tabernacle, it gives such tremendous flexibility. The chances for incompatibility between the dimmer and lighting instrument are dramatically reduced, so the threat of filament noise is rendered almost inconsequential.”

The ETC Eos lighting console was another new piece of gear in development during the design process. “It was a whole new platform for ETC,” says Gavin. “and LDS lighting personnel were comfortable in the role of Beta testing. ETC was still in the phase of fine-tuning the software for it, and LDS was willing to go through this development process, because it put them in a good position to have the exact features they wanted incorporated.” The Eos chosen for the Tabernacle is an 8K console with a Smartfade 2496 backup for theatrical lighting control.

The overall control package, in addition to the two racks of ETC Sensor+ sinewave dimming for the architectural lighting, consists of six racks of ETC Sensor dimmers for theatrical usage, one additional rack to handle the annual outdoor Nativity scene at Christmas time, plus an additional rack for UPS emergency broadcast. There are over 100 distribution receptacle devices located throughout the room, which also has an ETCnet Ethernet data distribution system, with 34 Ethernet tap locations. An ETC Unison system provides architectural lighting control.

“One of the most arduous jobs we had was understanding what existing circuitry had already been distributed to locations along the organ, and figuring out how we were going to rework and integrate additional distribution to improve the cyclorama lighting,” says Gavin. “Because there was no existing documentation, and the organ was closed off and protected on the site, we spent a lot of time working on this with the head lighting technician, Lorin Morse. Lighting devices were located behind the larger facade pipes, low on the organ front, and in the structural area behind the organ. LDS had been using conventional striplights at the rear of the organ to light rear wall and dome but the fixtures were not as effective as they wanted. Part of this renovation was redesigning the organ locations and fixtures, so the cyclorama was lit as evenly as possible. Ultimately, we worked with the LED light fixture manufacturer and did a
mockup. The covered spaces and irregular shape of the organ added to the challenges."

“The dome is basically an ellipse,” continues Gavin, “but, since the ceiling curves, your throws are getting shorter, but the tippy-top is longer. While some fixtures graze surfaces, others hit straight on. In our mock-up, we brought fixtures onto the choral area and looked at different lensing configurations to see what would work best for the dome geometries. It was mostly a matter of experimentation and a good deal of trial and error. We put fixtures in some very weird alcoves, and in locations on the back of the organ to fill out the patchy spots. Now, there are three sections of LED striplights per vertical swath and three fixtures at every location as you move around the cyclorama portion of the dome. The LED manufacturer had a four-cell, a 2×2 box that was very useful in these positions.”

The LED fixture used here is the Selador X7 Series, which incorporates 32 high-brightness 1W Luxeon LEDs in each foot-length of fixture; the product is billed as producing intense colors across the spectrum while rendering natural-looking pastels and white light and beautifully colored objects and skin tones; this digitally controlled lighting array yields over 60,000 color variations.

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LDS technicians developed the lighting fixture plot and design for services, events and broadcast,” Gavin says. “They knew exactly what they wanted, down to the custom white on all fixtures and accessories visible to the congregation. Auerbach Pollock Friedlander assisted the effort with specification writing and working closely with LDS to pull together the fixture package.”

The total lighting package for the space includes ETC Source Fours, Source Four PAR MCMs, Vari*Lite VL3000 and City Theatrical AutoYoke automated units, High End Systems Color Command and Wybron Nexera color-changing units, and Ocean Optics Seachangers, which can be attached to the Source Fours to provide silent dichroic color mixing.

The audio-video factor
Edward McCue and Richard Laidman were responsible for upgrading the sound environment, with McCue on acoustics and Laidman on audio. “Control over reinforced sound is necessarily very tight in this room,” notes McCue. “The marvelous but relentless geometry means that you can’t afford to just send energy in all directions, or the sound images will become unintelligible. I’ve never encountered a room so sensitive to sound. The Tabernacle is one of the best places in the U.S. to become aware of the impact of architecture on the ability to hear. You literally can hear a pin drop.”

For this reason, it was paramount to minimize any mechanical and electrical noise. In addition to sinewave dimming, the team segregated the video projectors behind glass in the attic. “The Church and the acousticians didn’t want the projectors hanging within the space,” says Mei, who designed the video systems. “We created two acoustically isolated, climate-controlled rooms to hold each projector, and cut projection ports in the side walls of the ceiling dome.”

Two motorized front projection screens, located on either side of the organ pipes, rise up vertically from custom-designed millwork cases installed behind the last row of choir seats.

With the audio system, the client continued its practice of opting for new technologies. “The very knowledgeable staff there makes its own decisions as you go along,” observes Laidman. “There were some decisions that came later in the project for which we provided infrastructure and they decided on products to fill in the blanks later. LDS always wants to be at forefront of what’s happening.”

The main sound reinforcement system isn’t in use during daily organ concerts or other acoustical events, so it was made demountable. “They don’t want the arrays hanging there when
not in use,” says Laidman. “That’s not too unusual for a modern concert hall, and that’s what this is in some sense. But they do need the new system to support popular music or orchestral/jazz ‘pops’ music that may be played on its own or accompany the choir.” A cable and winch system in the attic lowers the clusters to the rostrum for assembly and later hoists them back up.

There are 10 JBL VT4888 speakers in line arrays each side of the rostrum. “We made a custom rigging bar and harness so we could fly and hang another little cluster of three JBL VT4887s in line arrays behind to provide coverage to the side balconies,” says Laidman. He depends on line arrays for precise delivery and tight control of the sound pattern. “It conforms to the seating area you are trying to cover. You don’t want to create a lot of reflections or echoes. They work together and you get less falloff over distance.”

In addition to the JBL VerTec 4888s and 4887s suspended in the clusters, the sound rig includes 12 Renkus-Heinz TRX/61s for underbalcony coverage, two Duran Intellivox DS500s for balcony speech reinforcement, two Duran Intellivox DS280s and two DS180s for main-floor speech, four Renkus-Heinz PNX81/9s for the choir, two JBL VRX932LAs, providing additional front fill for the music system, plus four JBL SRX728S deployable subwoofers. “I think of this as a very egalitarian process,” says Laidman. “A person way off to the side, up in the balcony, or under the balcony will have pretty much the same listening experience as someone center front. I would try for the same in a theatre or concert hall, where a cheap ticket may provide a poor view but not poor sound.”

Also part of the main sound reinforcement system are 72 Electro-Voice 405s, making up the stage-lip line array built into the movable rostrum platform to provide infill sound to the first five or six rows. “It’s a horizontal version of a line array, with the same characteristics of a vertical array: Not having to play as loud, and being able to go farther,” says Laidman. “The strength and energy of the main clusters also serves those front rows, but the intelligibility and clarity come from the infill line array. If you point the main cluster at the front row, it will feed back—and if you don’t have the infill—the first few rows have to get their sound from 30’ over their heads.”

Laidman set up another kind of line array specifically for speech reinforcement, using Duran digital directivity synthesis loudspeakers. “They’re unit enclosures—not a lot of tiny boxes, but long, skinny boxes anywhere between six and 16’ tall,” says Laidman. Four of these are located on columns: Two closer to the rostrum, and two more are about two-thirds of the way back in the room. Another two sets, attached to the sides of the organ console, serve the balcony. “We used [Duran] DS280s and DS180s; they’re little 4” loudspeakers that are placed right next to each other, or more spread out, becoming farther apart as you get higher up in the unit. Each loudspeaker within these enclosures has its own power amp and own digital signal processing to steer the sound lobe according to the specific shape of the area being covered. Duran DDS software and signal processing make it possible to shape the front of the soundwave to approximately follow the line of a sloping floor, or wrap around a balcony face, and under and above the balcony as well.” Amplifiers include Crown I-T and CT Series units, plus a pair from QSC’s CX Series. A Yamaha PM5D-RH controls the system.

Other key pieces of sound gear include 12 Shure UHF-R wireless mics, two Lake Contour 26 DSPs and MediaMatrix Nion 8 DSP systems, a BSS OPAL FCS 966 graphic EQ, Furman PL-8 power conditioning, and Middle Atlantic racks. Kirkegaard also provided an Atlas Soundolier back-of-house monitor and paging system with fundamental ceiling loudspeakers, operated by the intercom system, which was designed by Auerbach.

The latter is a flexible and expandable digital matrix intercom system, and provides necessary full duplex communication throughout the facility through the use of master base stations, remote belt-pack units, and wireless headsets. The system also

The old and new Tabernacles, and the Temple’s foundations, in the 1870s
provides back-of-house paging, performance audio feed, and a cue-light signal system fully integrated and actuated by the digital matrix. Communication to production personnel is also provided by a closed-circuit television system, allowing distribution and control of pan/tilt/zoom cameras to the various technical operation positions within the facility. The communication system is by Clear-Com. The cue-light system includes a Clear-Com RLY-6 relay control module, Futurelec opto-isolated relay boards, and custom-fabricated and portable cue light panels with amber and green indicator LEDs.

The video and communications system design, including broadcast cameras, switchers, projection equipment, and Clear-Com communications systems, had to be, for the most part, invisible and retractable. “There is one camera that is fixed on the centerline of the Tabernacle, to the balcony face, on a robotic pan/tilt head, and that’s the only one fixed in public view all the time,” says Dan Mei. Two cameras, on motorized pylons, located on the left and right sides near the main cross aisle, rise out of the floor about 12’ on cylindrical lifts when summoned. The side balconies have two manned camera positions utilizing a camera trolley that clips onto a specialty balcony railing for live tracking shots.

The five cameras are all controlled remotely, via fiber-optic cable, from the control room in the LDS conference center several blocks away. “All that specialty hybrid camera cabling was run by LDS staff themselves,” notes Mei. Integrating connections in the rostrum itself took a lot of design coordination because of the movable sections. “We had to come up with clever ways to hide connection panels under the fixed structure to connect removable video screens built into the fronts of the seating modules and other temporary services,” notes Mei.

Because the audio and video responsibilities were divided between the two companies, Auerbach Pollock Friedlander and Kirkegaard worked closely to coordinate the AV wiring infrastructure and connection panels.

“The church wanted one point of contact for all the wiring,” says Mei. “Kirkegaard gave us their requirements and we integrated those with our panels. That worked out well. Of course, everybody has changes at one point or another, and we had to keep track of all the those changes, so there was a lot of infrastructure coordination back and forth between the two firms.” A secondary set of pan/tilt/zoom cameras for technical and production uses can be remotely controlled from various positions within the Tabernacle. The video control racks are located in a technical operations center in the basement, where there are also rehearsal rooms and a teleprompter control room.

**Reconfiguring the space**

“The Tabernacle is active almost 300 nights a year,” says Neville. LDS had a clear concept of the new modular rostrum and rigging functions, he adds: “We were all facilitators more than anything else, executing their vision in a construction environment. The lift systems and rigging were
designed to facilitate moving from event type to event type as seamlessly as possible. Whatever the configuration, it must look as if the event belongs in that space. The corollary goal was for the technology to be as unobtrusive as possible.”

Several large existing light trusses were relocated to serve the latter goal. “The entire design team decided not to try to hide them, but to move them out of the picture as much as possible,” says Neville. Trusses located directly over the rostrum were moved to the back of the house. Stage right and left trusses were small air compressor, open a false panel on the railing, plug in the compressor, turn it on, and it pushes the casters up 2” so they can roll around.” The “inflatable” casters are known as tri-casters or zero-throw casters. “They go exactly where you need them to go,” says Neville. “When you push the unit into its place squat and set it down, it stays right where you put it.”

The existing wooden roof trusses were relied on to rig the chandeliers and light trusses. “The roof is a barrel shape and at each end a quarter of a sphere,” says Neville. “The ‘king’

Neville: “The Tabernacle is active almost 300 nights a year. Whatever the configuration, it must look as if the event belongs in that space. The corollary goal was for the technology to be as unobtrusive as possible.”

moved as close to the wall as possible and painted to match the colors of the wall and ceiling.

Two custom lifts, activated by Gala Spiralifts, provide the base structure for the various rostrum configurations. “It’s a lift-within-a-lift setup,” says Neville. “The main lift can travel from the storage level all the way to the red carpet level. The smaller lift, contained within the larger lift, follows a shorter path and is primarily for orchestra mode. When the choir and orchestra perform together the orchestra is positioned nearest the audience and the choir is directly in front of the organ; this configuration echoes how the space was used prior to the renovation and was only slightly restructured.”

On top of the lifts are platforms created by Stage Right, and stage wagons created by Pook Diemont & Ohl (PDO). “The wagons are great,” says Neville. “Internal to each is a small hydraulic caster lift system. People moving the wagons take a triple job, working closely with PDO.”

The control systems for the lighting and the rigging are wireless. “In the case of the rigging automation system, there are several fixed permanent positions where the Nomad console can be positioned,” says Neville, “but to provide additional flexibility the devices can also be run from a belt pack. When somebody wants to work on a light truss, they just summon it and then send it back. We tried to provide as many tools as possible to reduce manpower. You can turn on the lights with one remote after you bring in the truss with another remote—meaning that a single technician can do it in sequence.”

All this technical work was being done in tandem with significant structural work. “The major scope of the project for us,” says Roger Jackson AIA, of FFKR Architects, “was to seismically upgrade the building, which consisted of strengthening the foundations, stone piers, roof trusses, roof diaphragm, and choir bowl, making structural connections between the foundation, walls, and piers, and connecting the floor to the walls and the trusses to the piers, strengthening the connection between the roof and plaster ceiling to the trusses, and stabilizing the existing ‘king trusses,’ the plaster ceiling system, and organ structure.”

The Tabernacle’s north and south underground structures comprises approximately 97,412 sq. ft. The mechanical, electrical, fire sprinkler, life safety, and audiovisual systems were removed and new, code-compliant systems installed. All the finishes were touched up or repainted in some way. Any new building elements were given particular attention to match the historical character and design found throughout the building. “The ultimate goal was to strengthen and fortify the building while still keeping the old, original Tabernacle,” adds Jackson. Today, the renovated Tabernacle looks more like its old self than it has for some 40 years.