



CASE STUDY

Visualization Laboratory

King Abdullah University of
Science and Technology (KAUST)

Thuwal, Saudi Arabia

Summary

King Abdullah University of Science and Technology

Inaugurated in September 2009, the King Abdullah University of Science and Technology (KAUST) is a graduate-level teaching and research institution situated on the Red Sea at Thuwal, 80 km north of Jeddah, Saudi Arabia. Funded by a \$10 billion endowment from its namesake Saudi monarch, and rising from bare desert in two years, the 36-square-kilometer KAUST campus encompasses state-of-the-art facilities that immediately place it in the forefront of world institutions for scientific inquiry. By forming partnerships with universities around the world, KAUST has created a global network for research across multiple academic disciplines, ranging from environmental and biological sciences to applied mathematics and chemical engineering. KAUST's leading-edge technology resources include Shaheen, the Middle East's most powerful supercomputer.



An Interactive, Multisensory Approach to Scientific Inquiry

Sonification (noun): The use of non-speech audio to convey information or perceptualize data.

The proliferation of networked supercomputer technology has generated a unique problem that affects nearly all fields of scientific research. The sheer amount of available data often makes it difficult for researchers to meaningfully evaluate and communicate the critical information extracted from the computers' colossal "number crunching."

One solution to this growing challenge is the emerging discipline of scientific visualization accompanied by sonification. With KAUST's adoption of large-scale three-dimensional video technologies and the Meyer Sound Constellation acoustic system and Matrix3 audio show control, researchers can view and manipulate massive amounts of data in an interactive, immersive, and ultra-high-resolution virtual environment.

Through establishment of the Visualization Laboratory, KAUST has vaulted to the forefront of this new discipline. With multiple rooms linked by fiber optic data networks, the Visualization Laboratory encompasses more than a dozen "sci-vis" systems of various types, ranging from precedent-setting, stereoscopic 3D environments to development rooms and lecture halls. The Visualization Laboratory expects to facilitate research into three-dimensional geological structures, oceanographic processes, and the effects of dynamic seismic and atmospheric activity on planned or existing infrastructure.



KAUST Visualization Laboratory Project Partners

Owner/Administrator

King Abdullah University of Science and Technology
Thuwal, Saudi Arabia

Principal Architect

HOK International
St. Louis, Missouri, USA
Principal designer: Bill Odell

Design, Engineering and System Integration

Mechdyne Corporation
Marshalltown, Iowa, USA
Lead designer: Tim Taylor
Audio designer: Mike Pedersen

Academic Partner / Design Consultant

California Institute for Telecommunication and Information Technology (Calit2)

University of California
San Diego, USA

Lead consultant: Peter Otto

Audio Systems: Design Consultant and Supplier

Meyer Sound Laboratories
Berkeley, California, USA

Academic Partnership: University of California, San Diego

To assure that their scientific visualization facilities would equal, if not supersede, any available elsewhere, KAUST administrators established a collaborative relationship with the California Institute for Telecommunications and Information Technology (Calit2) at the University of California, San Diego in developing the Visualization Lab. Calit2 assisted KAUST in outlining facility requirements, preparing Requests for Proposals, and consulting on staff appointments.

Design, Engineering, and Installation: Mechdyne Corporation

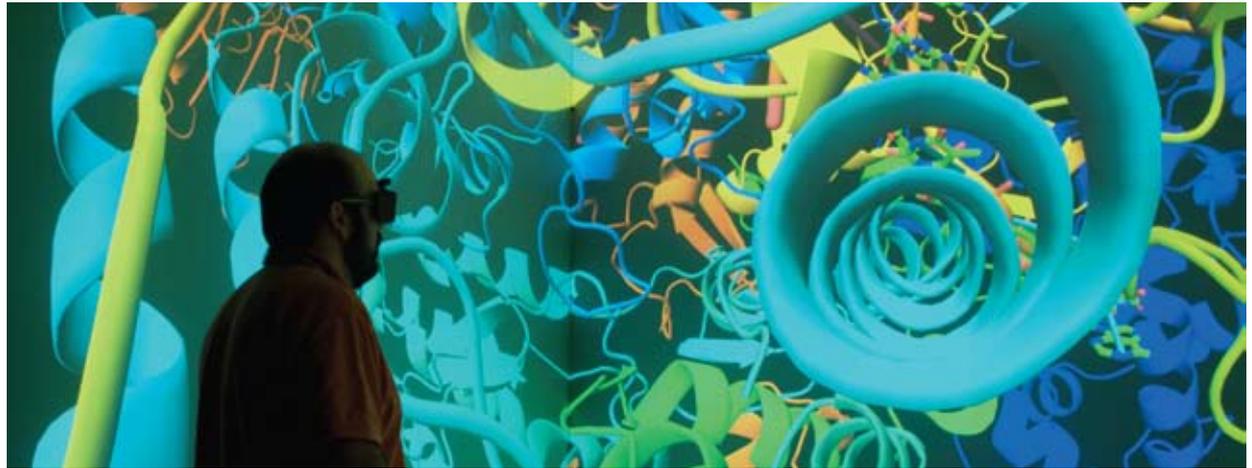
Mechdyne Corporation was selected for the design and engineering of the primary scientific modeling and visualization facilities at KAUST: a six-sided fully immersive virtual environment, a 75-seat 3D multipurpose room, a recording/control room, as well as additional visualization systems for research labs and lecture halls. Mechdyne was also contracted to provide systems integration, software and on-site technical support.

Advanced Audio Solutions: Meyer Sound

To add an unprecedented level of dynamic, fully immersive sonification to the main visualization environments, Meyer Sound Laboratories was selected as the principal source for digital audio systems and self-powered loudspeakers, along with associated design services and on-site technical support.

“It is my desire that this new University become one of the world’s great institutions of research; that it educate and train future generations of scientists, engineers and technologists; and that it foster, on the basis of merit and excellence, collaboration and cooperation with other great research universities and the private sector.”

King Abdullah Bin Abdulaziz Al Saud
(Source: www.kaust.edu.sa)



Meyer Sound Matrix3 and Constellation: Unprecedented Digital Control of Sound

The Matrix3 audio show control system and Constellation acoustic system, two powerful digital processing platforms from Meyer Sound, are at the heart of all networked audio systems in the Visualization Laboratory’s principal environments. Although developed primarily for applications in the arts and entertainment, Matrix3 and Constellation unlock new possibilities for creative use of dynamic sound information in scientific visualization. Principal designers at Mechdyne had been aware of these technologies since 1999, and found KAUST the perfect opportunity to take advantage of Meyer Sound’s advancements in spatial audio.

Matrix3: Precision Control of Timing and Movement in Sonic Space

The Matrix3 system was created to give sound designers essentially unlimited power to simultaneously play back multiple sounds with precision timing, and also freely move sounds through space by matrixing and panning the various sources through multichannel loudspeaker systems.

The power and flexibility of Matrix3 enable researchers here to extend the sensory reach of visualization environments through dynamic, interactive sonification. Using custom software that interfaces with Meyer Sound’s CueStation software, researchers can “tag” any object or event in visual space, assign a sound to it (natural or synthesized), and then program the sound to move interactively in the space along with the object. Additionally, sounds can be made to change in volume, pitch or tempo to reflect changes in the data streams they represent. Realistic sounds may be used for natural sciences such as zoology and marine biology, whereas disciplines such as biochemistry or engineering would use synthesized sounds to convey abstract information.

Matrix3’s fully modular hardware and software platform is freely configurable to meet user specifications. The powerful LX-300 processor can be configured with multiple inputs and outputs using combinations of analog, AES3 digital and CobraNet networked signals. CueStation software implements flexible tools for multichannel mixing, signal matrixing, and dynamic panning using the intuitive graphical SpaceMap programming feature. Integrated Wild Tracks hard disk playback provides 24 source tracks with software-driven features for track grouping, cueing, and external device playback control.



Constellation: Active Acoustics for Virtual Spaces

Whereas Matrix3 controls the timing and movement of sounds within a fixed acoustical space, Constellation recreates the perceived acoustical characteristics of the space itself. By altering both early sound reflections and room reverberation, one physical space can assume the acoustical identity of many. For example, a small presentation room can assume the convincing acoustical signature of a deep cave, a submersible research vessel, the Grand Mosque, or a wide-open desert canyon.

It's important to note that Constellation is not simply reverberation added to sound playback. Rather, it is a fully responsive, real-time system that employs multiple microphones in the space, and a dense array of surrounding loudspeakers to digitally recreate the multiple, decaying sound reflections of a software-defined virtual space. The effect is absolutely realistic, as is critical for Constellation's primary application—providing the rich acoustic ambience needed for symphonic and choral music in acoustically “dry” performance venues.

Constellation and Matrix3 share much of the same core digital technology. In fact, a suitably configured Constellation hardware frame can generate all the multichannel sound manipulation features offered through CueStation software—as is done in the Visualization Lab's two main environments.

As with Matrix3, Constellation comprises a fully integrated hardware and software platform. An MS–Constellation processor contains the essential communications hardware, and a separate MS–VRAS processor incorporates the digital signal processing for the proprietary VRAS acoustical algorithms. Additional expansion frames provide inputs and outputs for the multiple microphones and loudspeakers needed to create a natural acoustical ambience. The desired early reflections and reverberation are reproduced by multiple self-powered Meyer Sound loudspeakers: smaller mid-high systems for non-localized ambient sound plus compact subwoofers that extend reverberation effects to the lowest octaves.

Challenges

- Leading-edge design: few precedents or established solutions
- Utmost audio flexibility and realism demanded for the research space
- Loudspeakers required in problematic acoustical environments

Requirements

- Provide the world's most advanced facilities for three-dimensional modeling, visualization and sonification of scientific data
- Adapt to a wide range of research disciplines
- Seamlessly integrate dynamic real-time movement of images and sounds

Benefits

- Realistic visual and audio for interpreting large, complex data sets
- A high-speed audio network infrastructure for high-level collaboration
- Stimulates creative problem solving
- Enables students to grasp concepts at multiple levels
- Attracts faculty and researchers from around the world

“We wanted to integrate technologies that really hadn’t been paired before to create an enhanced 3D environment. You’re not just seeing a 3D visual, you’re also hearing dynamic three-dimensional audio cues.”

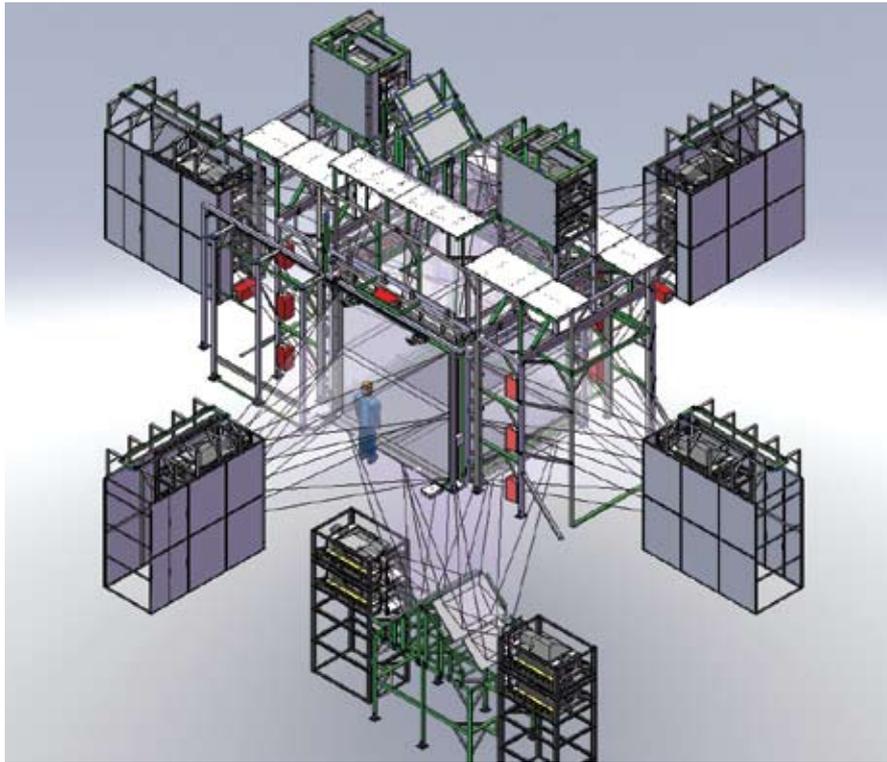
Tim Taylor
Designer, Project Engineering
Mechdyne Corporation



CORNEA Immersive Virtual Reality Environment

A fully immersive 3D virtual reality environment, CORNEA is an advanced version of the original four-sided immersive environments developed in the early 1990s. CORNEA is now the brightest and highest-resolution CAVE environment in the world, and one of only two six-sided installations in the world to employ 24 digital projectors each with 4K resolution (four per wall) to create 100 million pixels of stereoscopic 3D visual information. CORNEA is also the first research environment to offer the integrated sound spatialization and variable virtual acoustics of Meyer Sound Matrix3 and Constellation.

For the CORNEA audio system, 20 UPJunior loudspeakers are mounted 18 inches outside the room and point into it. These loudspeakers provide audio support of visualizations and deliver the acoustic energy that Constellation produces. Miniature microphones inside the sonic environment pick up sounds for Constellation processing. They also pick up discussions and commentary from scientists to be monitored in the other facilities and recorded for archiving purposes.



Loudspeakers are mounted outside of CORNEA's rear projection screens to complement twenty-four 4K video projectors.

CORNEA

Meyer Sound Audio Components

- 20 UPJunior VariO loudspeakers
- 4 UMS-1P subwoofers
- 16 Cardioid microphones
- 2 MS-Constellation processors
- 2 MS-CEXP expansion processors
- 1 MS-VRAS processor
- 1 MS-WTRX Wild Tracks module

Main Visualization Components

- 24 Sony SXR4 4K projectors
(10,000 lumens each)

Each side of the CORNEA cube is ten feet (three meters) across, and the environment can accommodate up to eight researchers at a time.

Because of the sound absorbing properties of the rear-projection screens, the nominal acoustics of CORNEA are not consistent with the perceived space. In most rooms, low frequency reverberation is as long or longer as that of higher frequencies. In CORNEA, the opposite occurs. A Constellation setting was developed for CORNEA to increase the low- and mid-band reverberation times with minimal change of the high frequency reverberation times to, in essence, "normalize" the room acoustics of the space. As a result, users comment that the experience of being in CORNEA is less claustrophobic and fatiguing.

“Constellation is stunning in its ability to create realistic, fully immersive sonic spaces. We’re already using it to communicate subtle audio cues about the nature of the space a user is moving through. It makes the research and exploration experience more engrossing and user-friendly.”

Zachary Seldess
Audio Systems Coordinator
and Developer
Visualization Laboratory

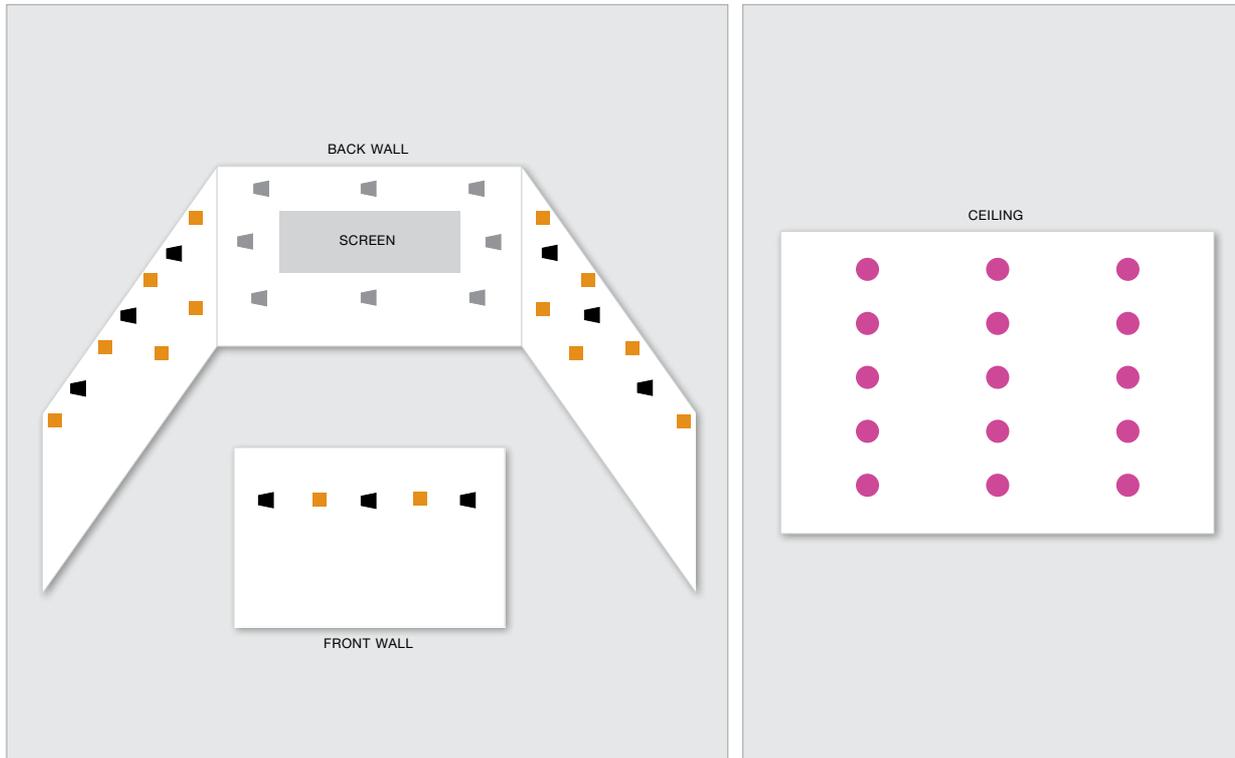


Multipurpose Room (MPR)

With seating for up to 75, the Multipurpose Room (MPR) serves as the Visualization Laboratory’s principal space for larger group meetings and intensive collaborative research sessions.

The front wall of the MPR is dominated by a 10’ x 20’ Mechdyne PowerWall™ which employs eight Sony 4K projectors to provide a 32 million pixel stereoscopic 3D display. A ninth “utility” projector is used for 2D videoconferencing and presentation applications. Three large plasma screens are mounted on side walls for additional imaging option. HD cameras and wireless microphones are available for videoconferencing sessions.

Extensive, high-speed fiber optic lines interlink the MPR with the central computer cluster, the CORNEA environment, the Recording and Control Room and the main development room. The MPR can tap 51 potential sources, and distribute 31 of them out of the MPR to other visualization systems.



Multipurpose Room

Meyer Sound Audio Components

- 8 UPJ-1P VariO loudspeakers
- 9 UPJunior VariO loudspeakers
- 15 Stella-8C installation loudspeakers
- 14 MM-4XP miniature loudspeakers
- 4 500-HP subwoofers
- 16 Cardioid microphones
- 2 MS-Constellation processors
- 2 MS-CEXP expansion processors
- 1 MS-VRAS processor
- 1 MS-WTRX Wild Tracks module

Main Visualization Components

- 9 Sony SXR4 4K projectors
- 1 20' x 10' (6.09 m x 3.05 m) Stewart rear projection screen
- 1 Mechdyne Opti-Track multi-camera optical motion tracking system
- 6 Sharp 65"/80" plasma displays
- 3 Sony HD BRC-Z700 videoconferencing cameras

For audio spatialization and acoustical enhancement, the MPR provides a fully immersive sonic environment as implemented through Meyer Sound's Matrix3 and Constellation technologies. The surround/spatialization system employs eight UPJ-1P loudspeakers around the front screen, nine UPJunior surround loudspeakers on the side and back walls, and 500-HP subwoofers. A complement of 29 additional small loudspeakers (MM-4XP and Stella-8C) on the walls and ceiling enable Constellation's variable acoustics. A 32-channel CobraNet digital audio link interconnecting the source computer cluster, MPR, and CORNEA allows researchers in the MPR to experience the same dynamic spatial effects and acoustical environments as those perceived inside CORNEA.

In the MPR, Constellation also implements the voice lift acoustical enhancement feature that markedly improves spoken word intelligibility and thus eliminates the need for presenters or participants to wear microphones in the room. (The wireless microphone systems are needed for videoconferencing only.)

“Constellation and Matrix3 are integrated seamlessly with the video and control systems. All the components are complementary and create a true synergy that not only builds a compelling virtual world, but the system can monitor, record, and playback as well.”

Tim Taylor
Designer, Project Engineering
Mechdyne Corporation

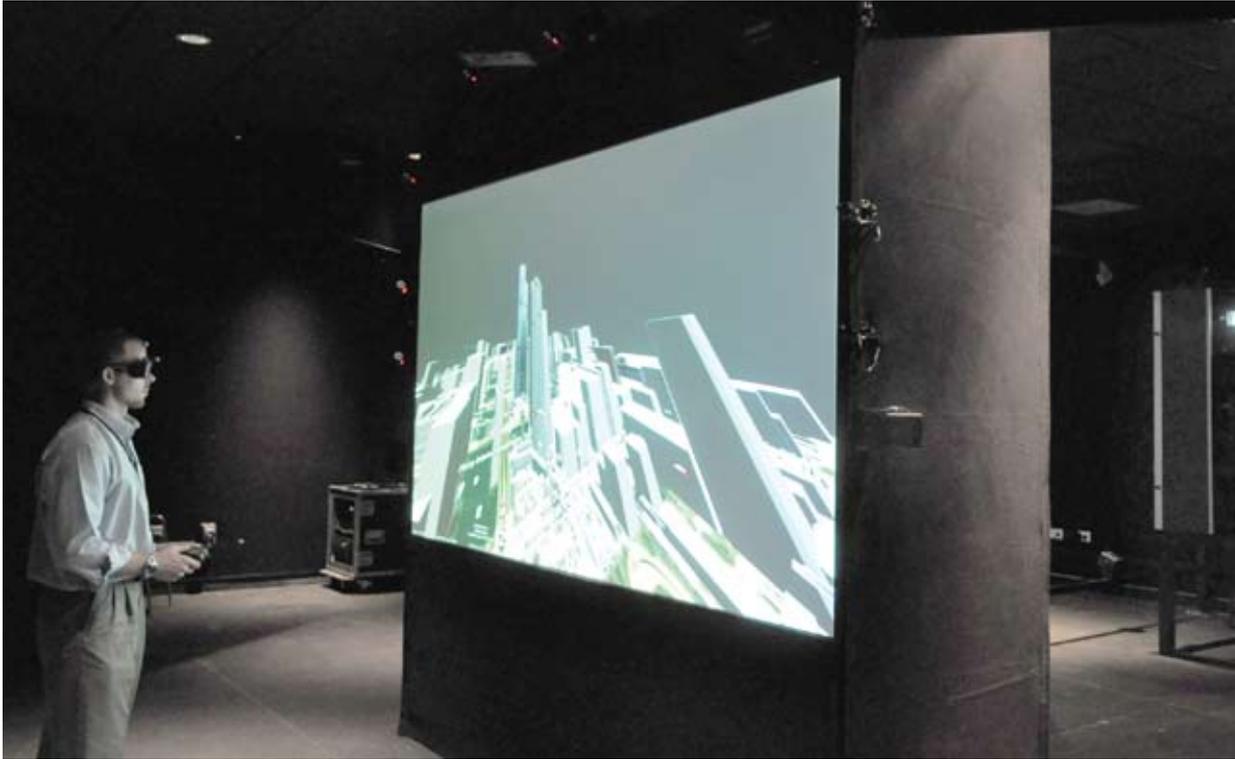


Recording and Control Room

Recording and Control Room

The Recording and Control Room provides facilities for recording, playing back and archiving visualization and audio sonification content as experienced in CORNEA and the MPR. It forms the fiber optic “nerve center” of the multi-room visualization complex, where high-speed Ethernet connections enable free exchange of data and audio among environments. The Recording and Control Room also includes facilities for video format conversion and remapping of both visual images and audio spatial content.

The audio system layout is designed for maximum flexibility, allowing researchers to accurately scale and map sounds for any of the other three linked environments. Five UPJunior loudspeakers work in conjunction with the subwoofers for conventional 5.1 surround monitoring. Alternatively, the 20 MM-4XP loudspeakers can be mapped along with the four small subwoofers to recreate the dynamic spatial audio effects experienced in CORNEA and the MPR.



Development System One

Development System One

Development System One is a scaled-down version of the larger collaborative environments. It allows researchers to develop, refine and revise content in a fully compatible yet user-friendly “offline” laboratory setting.

A High-Speed Networked Audio Infrastructure

The entire Visualization Laboratory is interconnected by 10 Gigabit Ethernet fiber optic links, along with a parallel 100 Megabit dedicated to audio transport. All Matrix3 and Constellation systems are equipped with CobraNet input and output cards, enabling real-time sharing of 32-channel bidirectional audio among the three main audio environments: CORNEA, MPR, and the Recording and Control Room. A 16-channel bidirectional link connects to Development System One.

Recording and Control Room

Meyer Sound Audio Components

- 20 MM-4XP miniature loudspeakers
- 5 UPJunior VariO loudspeakers
- 4 UMS-1P subwoofers
- 2 Matrix3 primary LX-300 processors
- 2 Matrix3 expansion I/O frames
- 1 MS-WTRX Wild Tracks module

Main Visualization Components

- 3 LCD flat panel displays

Development System One

Meyer Sound Audio Components

- 12 MM-4XP miniature loudspeakers
- 2 UMS-1P subwoofers
- 1 Matrix3 primary LX-300 processor
- 1 Matrix3 expansion I/O frame
- 1 MS-WTRX Wild Tracks module

Main Visualization Component

- 5.25' x 10' Mechdyne 3D PowerWall™ (8 million pixel)

“Meyer Sound has provided absolute quality control for their hardware and software at the Visualization Lab. We’re developing our own software applications and infrastructure, and educating students and faculty about the space, and what they can do with it. Because of the systems’ stability, our staff can press a few buttons and feel confident that any audio system will perform as expected.”

Zachary Seldess

Audio Systems Coordinator
and Developer
Visualization Laboratory



AESOP: A 40-Megapixel tiled display wall

Visualization Laboratory Showcase

The Visualization Laboratory Showcase comprises five separate visualization environments, all sharing the large open space in the glass-enclosed lobby area of the AI-Khawarzimi Mathematical, Computer Sciences and Engineering Building.

During public events such as KAUST’s inaugural ceremonies, the Showcase provides a platform for demonstrating the technological capabilities of the Visualization Laboratory. At other times it serves as an active laboratory for various visualization projects initiated by faculty and students.

The Visualization Laboratory Showcase concept was developed by Calit2 at the University of California, San Diego in collaboration with the Electronic Visualization Laboratory at the University of Illinois, Chicago. The systems were prototyped and tested (as a whole or in part) by Calit2 in San Diego, and then installed at KAUST with logistical and technical support from Mechdyne Corporation.



MM-4XPD miniature directional loudspeakers

NexCAVE is a scalable, modular 3D environment. As implemented at KAUST, it is configured as a 21-tile system using JVC X-pol video screens for visualization elements. Surround sound is provided by Meyer Sound MM-4XP loudspeakers and a UMS-1P subwoofer.

REVE (Rapidly Expandable Visual Environment) is an 18-tile system employing the French-developed Alioscopy technology which displays 3D visuals without requiring the viewer to wear special glasses.

AESOP is a 40-tile display featuring 52" NEC narrow bezel panels that enable large scale, near-seamless HD images without use of projection.

OptiPortal is a scalable tiled display that serves as the visual interface to the OptiPuter, a global-scale computing system tied together by tens of gigabits of networking. Two OptiPortals are featured in the KAUST Showcase.

Showcase Systems

Meyer Sound Audio Components

NexCAVE Dedicated System

- 5 MM-4XP miniature loudspeakers
- 1 UMS-1P subwoofer

Other Systems

- 5 MM-4XPD miniature directional loudspeaker
- 2 UMS-1P subwoofer

“We were inspired by KAUST to complement the best visualization facilities with unprecedented capabilities in the auditory domain. Meyer Sound, Mechdyne, and the Sonic Arts Group teamed up to deliver these state-of-the-art 3D sound systems. We are extremely proud of the results.”

Peter Otto, MFA

Director, Sonic Arts R & D
CalIT2/UCSD

Director, Music Technology
UCSD Department of Music



King Abdullah University of Science and Technology



Calit2 and the University of California, San Diego

Project Partner Profiles

King Abdullah University of Science and Technology

The King Abdullah University of Science and Technology was inspired by the decades-long vision of the Saudi Arabian monarch, The Custodian of the Two Holy Mosques, King Abdullah Bin Abdulaziz Al Saud.

A graduate-level research university, KAUST is governed by an independent Board of Trustees. Admission to the university is merit based, and is open to men and women from around the world. The inaugural class of about 400 comprises only about 15% Saudi Arabian nationals, with the next largest student contingents from China, Mexico, and the United States. All students receive fully paid scholarships. KAUST offers advanced degrees in 11 fields of study.

Academic and research programs at KAUST focus on four areas of the sciences and technology:

- Resources, Energy and the Environment
- Biosciences and Bioengineering
- Materials Science and Engineering
- Applied Mathematics and Computation Science

To support these core research thrusts, KAUST has established nine multidisciplinary research centers, of which the Visualization Laboratory is one.

Calit2 and the University of California, San Diego

The California Institute for Telecommunications and Information Technology (Calit2) is an academic research institution jointly operated by the University of California, Irvine, and the University of California, San Diego (UCSD). The institute's principal research facilities for 3D immersive visualization and sonification are located in Atkinson Hall on the UCSD campus. In addition to CAVE environments similar to those at KAUST, Atkinson Hall also houses a 200-seat Digital Cinema Auditorium with a full complement of Meyer Sound's Cinema Experience loudspeakers. UCSD's new Conrad Prebys Music Center also houses several Meyer Sound installations, including a Constellation system in the Experimental Theater that is similar to the one in the KAUST Visualization Laboratory's MPR.



Mechdyne Corporation



Meyer Sound Laboratories

Mechdyne Corporation

Mechdyne is the world's largest company dedicated to consulting, design, and development of turn-key immersive, networked, and collaborative visualization solutions. The company provides advanced display technology, audio/visual systems design and implementation services, as well as immersive and interactive software development, professional services and global technical support. Headquartered in Marshalltown, Iowa, Mechdyne's customers include leading government laboratories, research organizations, universities, energy companies and a variety of 'edutainment,' design/manufacturing and other users of advanced visualization technology.

In addition to the principal visualization and sonification environment with Meyer Sound systems, Mechdyne was contracted to supply and install other visualization systems requiring only conventional audio support. Two lecture halls were equipped with PowerWall™ 3D displays, each with four 4K projectors for 16 million stereoscopic pixels. Two additional development rooms were outfitted for visualization: one with two portable Mechdyne ROVR™ HD display systems, and a third with a 61-inch HD resolution 3D Review Station. Mechdyne also provided proprietary visualization software packages, including CAVElib™, vGeo™, and Conduit™.

Meyer Sound Laboratories

Meyer Sound was established by John and Helen Meyer in 1979, and both founders still guide the company today as CEO and Executive Vice President, respectively. Although Meyer Sound has grown to assume global leadership in audio technology, it still operates as a privately held and fully independent company — and is thus able to quickly focus resources on responding to customer needs and continuing its tradition of pioneering innovations.

Under John Meyer's personal leadership, the company's team of research engineers has garnered 40 U.S. and foreign patents, along with dozens of prestigious industry awards. All Meyer Sound products, critical internal components included, are made exclusively at the company's headquarters and factory in Berkeley, Calif.

“KAUST is a landmark in visualization — an integration of the world's most sophisticated and realistic sound system paired with the most advanced, fully immersive virtual reality environment yet created. The result is an unsurpassed visual and auditory experience. The products and expertise of Meyer Sound were instrumental in achieving this ambitious goal.”

Jeff Brum

VP of Marketing and
Business Development
Mechdyne Corporation

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