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INNOVATIONS DURING RENOVATIONS: EVOLVING TECHNOLOGIES AND NEW MATERIALS FOR AN ENCYCLOPEDIC UNIVERSITY MUSEUM

CAROL SNOW

ABSTRACT

Founded in 1832 as the country’s first college art collection, the Yale University Art Gallery recently completed a phased renovation and expansion as part of Yale University’s Master Plan for the Arts Area serving Yale, New Haven, and visitors from around the world. Guided by Art Gallery Director Jock Reynolds, New York’s Ennead Architects elegantly reunited three distinctly different buildings: the 1866 Ruskinian Gothic Street Hall originally built as the Yale Art School, the 1928 Italianate Gothic Old Yale Art Gallery, and the 1953 Louis Kahn building. At a cost of $135 million, the project reversed more than 280 years of accumulated, deferred maintenance, vastly increasing exhibition space to allow over 4,000 works of art to be displayed, and creating new study galleries and classrooms to fulfill the teaching museum’s mission “to encourage appreciation and understanding of art and its role in society through direct engagement with original works of art.”

During the last phase of renovations, the conservation department was tasked with treating over a thousand objects from eleven curatorial departments in less than three years. Support from interdepartmental museum staff allowed research and development of new materials and techniques for major installations and conservation projects. Treatments ranged from high precision, dry removal of tons of reinforced concrete to passive preservation of experimental materials used by living artists. Collaborations with engineers, fabricators, art handlers, exhibition designers, and curators led to innovative use of evolving technologies. New applications of 3D scanning, computer numeric controlled machines, and composite materials redefined reversibility and restoration and offered new options for collection display and collection sharing.

1. RENOVATIONS

If home renovations rank among the top 10 stressful life events, where do museum renovations fall on stress scales for both museum staff and museum collections? Many of us have experienced and survived planning, deinstallation, packing, moving, temporary storage, treatment, repacking, reinstallation, and even renovations of previous renovations. The numerous logistical challenges of museum renovations require incredible coordination, collaboration, flexibility, and new approaches to tackle unforeseen problems.

On December 12, 2012, the Yale University Art Gallery celebrated a gala reopening after 14 years of planning, fundraising (including through a recession), demolition, expansion, construction, and reinstallation. During all phases of the renovation project, the museum remained committed to exhibition of a portion of its permanent collections as well as traveling and temporary exhibitions that included a special conservation exhibition in 2009. A loan moratorium was not consistently enforced, so there were loans and collection sharing initiatives with other college and university museums. Teaching also remained a high priority.

The project was phased to first renovate the most modern of the Art Gallery’s three buildings, the 1953 Louis Kahn building, so that representative artworks from all curatorial departments would remain on display during renovations, thereby guaranteeing that no Yale class would be deprived of learning from the collections. All other art was packed into high-density systems that made innovative use of a computer numeric controlled (CNC) machine to customize packing (Gallup and Harlow 2006) and moved out of storage and exhibition spaces to an off-site facility purpose built for library storage and ingeniously adapted for compact, high volume storage of soft-packed works of art.
After completion of the first phase in 2006, ambitious plans for renovating the Art Gallery’s 1928 and 1866 buildings included a reconsideration of staffing needs. In 2008, the Art Gallery decided to hire its first full-time objects conservator. Although by then most collection objects had been deinstalled, crated, and stored away, curators saw this phase of renovations as an opportunity to pursue major three-dimensional (3D) object conservation projects, such as Byzantine floor mosaics and an 18th-century Connecticut period room. Some of these collection objects had never been displayed because of their poor state of preservation and/or the lack of exhibition space. In 2010, additional art handlers were brought on board for the two-year process of pulling, repacking, and reinstalling works of art as renovated galleries became available. Condition assessments and conservation treatments were, by necessity, done as objects were pulled for repacking for the reinstallations. A postgraduate fellow in objects conservation was hired to assist with the daunting task of keeping up, like Lucy and Ethel in the chocolate factory, with the virtual conveyor belt of objects in need of conservation and digital photography. Pre-program interns also helped and experienced the intense workload and gratifying results.

This article presents examples of ambitious conservation projects that pushed museum staff beyond our usual routines and treatment protocols. The renovations inspired and challenged us to find new materials and adapt evolving technologies by working with teams of architects, art handlers, artists, collections staff, conservators, curators, designers, engineers, fabricators, exhibitions staff, lighting specialists, registrars, riggers, technicians, and scientists. Summaries of 10 case studies are discussed here, with lists of works of art and materials and suppliers provided at the end of the article.

2. LIVING ARTISTS AND FABRICATORS

Working in an encyclopedic university museum offers the rare and wonderful opportunity to collaborate with artists and fabricators; such experience somehow seems innovative in its own right. Artists who answer conservation questions effectively preserve their art as conservators become the messengers and the caretakers. Two of these projects were undertaken in very different ways: one involving a major intervention and the other taking a more conceptual approach.

2.1 CLAES OLDENBURG AND THE LIPPINCOTT BROTHERS

Many accessioned Art Gallery sculptures are installed across the Yale University campus, among them is Claes Oldenburg’s *Lipstick (Ascending) on Caterpillar Tracks*, fabricated initially in 1969 and reworked in 1974 (fig. 1). Concurrent with the Art Gallery’s renovations, the University also renovated the college and courtyard where the sculpture is installed, thereby presenting an opportunity to address the damaging effects of years of exposure to New England weather and gregarious students when little or no routine maintenance had ever been done. A major conservation treatment overseen by the original fabricators Donald and Alfred Lippincott (who would also serve as go-betweens for all communications with Claes Oldenburg) began with a thorough condition assessment to develop a treatment strategy. The COR-TEN steel, painted steel, painted aluminum, and painted fiberglass sculpture were disassembled. The steel caterpillar track components were taken to a local welding company, and the aluminum and fiberglass to a boatyard in Rhode Island that was equipped to deal not only with large hulls but also colossal lipsticks. Working in close collaboration with Oldenburg, the Lippincott brothers proposed and received approval for alterations to the steel plate construction in order to improve welded joins and provide slightly more space between steel plates to prevent corrosion-causing debris from becoming trapped. Because Oldenburg had kept the original paint samples (fig. 2) in a file folder unaffected by light, excellent color matches were easy to make in epoxy and acrylic polyurethane paints. Oldenburg
Fig. 1. After treatment. Claes Oldenburg, *Lipstick (Ascending) on Caterpillar Tracks*, 1969, reworked in 1974, painted steel, aluminum, and fiberglass, 670.6 × 594.4 × 332.7 cm, Yale University Art Gallery, 1974.86 (Courtesy of Yale University Art Gallery)

Fig. 2. Original paint samples for *Lipstick (Ascending) on Caterpillar Tracks* provided by Claes Oldenburg (Courtesy of Yale University Art Gallery)
weighed in on every step of the welding and painting processes. He joined us for the reinstallation of the restored sculpture and was very happy to see his sculpture restored to its 1974 condition (fig. 3).

2.2 MATTHEW BARNEY AND STUDIO ASSISTANTS

For an inaugural temporary exhibition of contemporary art entitled Once Removed, Matthew Barney’s 1991 Unit BOLUS—Wad in, CONDITION, Wad out. (disciplinary funnel) was reinstalled in a Kahn gallery near a west-facing glass wall where December afternoon sunlight poured into the space. The sculpture consists of a petroleum jelly dumbbell on a stainless steel cooling unit, which malfunctioned when it was plugged in and could not keep up with rising afternoon temperatures. Conservation issues resulted from condensation on the steel plates and major slumping of the second-generation dumbbell provided by the artist. Matthew Barney and his studio assistants graciously advised us on replacement heat sinks and other parts as well as the dumbbell itself. They invited us to their studio and kindly provided a silicone mold for casting more dumbbells, a can of the correct mixture of petroleum jelly, two new cast petroleum jelly dumbbells of the correct size and composition, as well as plaster dumbbells to be used as models for future mold-making. In addition, they provided the sources of the materials, specific directions for making additional dumbbells, and clear instructions regarding when to destroy dumbbells that exceed an appropriate lifespan. Thanks to their generosity, future exhibition of the conceptual sculpture will be possible for many years. Recorded interviews will remain a key component of the conservation documentation.

3. NONWORKING ART AND WORKING MODELS

The Art Gallery collections include examples of objects with working components as diverse as 18th-century American clocks and Thomas Wilfred’s 20th-century light sculptures, or Lumia. Another
A working work of art in the collections is Marcel Duchamp’s 1920 *Rotary Glass Plates (Precision Optics)* (fig. 4), formerly titled *Revolving Glass Machine*, which was part of Katherine Dreier’s Société Anonyme collection that she donated to the Art Gallery in 1941. It consists of five off-the-shelf glass blades painted with black and white stripes on the ends so that when they are spun by an electric motor, a hypnotic, 3D spiraling effect can be seen by the viewer. The longest blade broke when Duchamp was experimenting with his machine, allegedly coming close to decapitating his friend Man Ray who was photographing it, and was replaced by Duchamp. In 2007, the longest blade broke when being crated during a traveling exhibition of Société Anonyme objects. Research and collaboration ensued to make a replacement blade and, more importantly, to make a safe, working model for study purposes. The two projects were carried out simultaneously to maximize materials research and collaboration among conservators, curators, engineers, and fabricators, as well as Yale Environmental Health and Safety.

Fig. 4. *Rotary Glass Plates (Precision Optics)* in action. Marcel Duchamp, *Rotary Glass Plates (Precision Optics)*, 1920, painted glass, iron, electric motor, and mixed media, 165.7 × 157.5 × 96.5 cm, Yale University Art Gallery, 1941.446a-c (Courtesy of Yale University Art Gallery)
3.1 REPLACEMENT BLADE FOR THE ORIGINAL SCULPTURE

The glass blade that broke in 2007 measured 39 1/8 in. long by 5 1/2 in. wide by ¼ in. thick and, like the other original glass blades, had three holes drilled in the middle of the blade for the brass hardware attachments that secured the blade to the central shaft. These holes were mechanically weak points where failure was likely to occur, and it did. New glass was ordered, similarly off-the-shelf from a local glass supplier, with the same dimensions and holes. Because commercial sheet glass is now manufactured in China, there was no way to control the color or match what was available in the United States in 1920. The new glass was a bluer green and could not receive the same slight bevel as the original. Instead, a better and safer, chemically annealed glass was obtained with acceptable color, thickness, and bevel from Depp Glass, the same glass company that provides structural glass for Apple Stores. Acrylic paints were used for the reverse painting of the black and white stripes, taking into account the optical qualities of the new glass and simulating every detail, including drips, of the aged lead white and carbon black oil paints used by Duchamp.

3.2 WORKING ROTARY GLASS MODEL

The goal of creating a working model (fig. 5) was to reproduce the original sculpture as faithfully as possible to demonstrate the optical illusion for special seminars using safe and durable materials and
technology following strict Yale Environmental Health and Safety guidelines. For the base, welded and powder-coated tubular steel was used instead of $2 \times 4$ pieces of wood. Lockable, leveling casters were added to facilitate movement of the machine and provide maximum stability when the model is in use. After testing various laminated and annealed glass samples, the same glass and acrylic paints as those used for the replacement blade were used for the model. The maximum operating speed of the original motor was found to be 406 RPM, so a $\frac{1}{4}$-horse power, three-phase motor with a variable speed drive was used. It operates by converting 120-volt electricity from a standard outlet into three-phase and then a control is used to adjust the RPM. Even the Yale safety officers were impressed by the visual effectiveness of the spiraling, 3D cone achieved by the working model.

4. ROTATIONS FOR TEXTILES

From rotating glass we move to rotating textiles, i.e., facilitating regular rotations of textiles from the Indo-Pacific and American Decorative Arts Departments. In collaboration with our Exhibits Department, Conservation has utilized new composite panel systems fabricated to our specifications by SmallCorp (fig. 6). They combine a perforated steel sheet front, Ethafoam core, and Dibond back. The

![Fig. 6. SmallCorp schematic showing textile panel construction (Courtesy of Yale University Art Gallery)]
panel is covered with color-matched fabrics used throughout our exhibition spaces. They allow a variety of mounting systems to be used: magnets, pins, and Velcro/magnet combinations. Through the use of the new composite panels and rare earth magnets, textiles can be hung within an hour and deinstalled within minutes, usually without any invasive stitching. A range of magnet sizes, shapes, and strengths are available. Adhesive-backed ultra suede can be applied to the magnets as a cushioning layer, and the magnets themselves can be toned with acrylic paints to match the color of the textile. An interlayer of toothy cotton flannel is held by friction behind the textile and by double-sided tape to the fabric-covered composite panel to improve the mounting technique. Fragile silk ikat, printed cotton, hooked wool bed rugs, and other artifacts have been installed with this system (fig. 7).

5. ROMAN HORSE ARMOR

Magnets were also used in the installation of a ca. 165–256 AD Roman horse armor (fig. 8) fabricated in antiquity from steel scales attached with strips of rawhide to linen. Leather trim remains on some edges of the armor. It is one of two such horse armors from the Graeco-Roman site of Dura-Europos; the other is in the National Museum in Damascus and is made of copper alloy scales. In a previous treatment the horse armor was stitched to a stable polypropylene mesh backing (Sease 1987). For the current exhibition, a new secondary support was fabricated using a 3D scan of a horse downloaded from the Internet. A CNC machine was used to cut an Ethafoam horse body to serve as a form for making a fiberglass and epoxy shell with some of the horse contours incorporated into it. A minimal wood structure supports the shell from within and black Volara covering the shell provides cushioning to
receive the horse armor. Rare earth magnets positioned on the interior of the shell help distribute the 40-lb. weight of the horse armor, reducing stress on the ancient rawhide stitches and linen backing.

6. INFRASTRUCTURE FOR AN ANCIENT ALTAR

Dura-Europos, the site on the Euphrates River in Syria that Yale excavated in the 1920s and 1930s, also yielded among thousands of other artifacts and wall paintings, the remains of a cave-like altar, or mithraeum, with wall paintings and limestone reliefs dedicated to the worship of Mithraism, a mysterious religion practiced by Roman soldiers all around the Roman Empire. At the time of excavation, the painted surfaces were consolidated with polyvinyl acetate and the gypsum wall plaster was backed with plaster of paris and a lattice of wood strips secured with plaster and hemp. Sections were removed that preserved the uneven morphology of the mithraeum.

The ancient wall paintings and modern field treatment materials have remained in good condition since arriving at Yale from Syria in 1933, permitting several installations of the mithraeum over the years. The 2012 reinstallation was done in collaboration with museum technicians to create an elaborate wood infrastructure (fig. 9) with sliding elements allowing each section of the wall paintings to be well supported and free-hanging. This design minimized the need for additional conservation. Occasional reinforcement of the 1930s wood lattice with fiberglass and epoxy, stabilization of a few joins, and localized consolidation of paint with acrylic resins were the only treatments necessary. A free-standing welded steel mount was made to support the two polychromed limestone reliefs. They, too, received minimal treatment during which traces of gold leaf were discovered on the figure of Mithras.

The mithraeum was reconstructed at an off-site conservation facility and then partially disassembled for transport. The infrastructure allows loans of individual sections to other institutions. It is reconstructed more or less in the fragmentary condition it was in when excavated. For reinstallation in the Dura-Europos Gallery (fig. 10), a scenic painter from the Yale University School of Drama provided
Fig. 9. Detail of infrastructure for *mithraeum* (Courtesy of Yale University Art Gallery)

Fig. 10. *Mithraeum* installed in Dura-Europos Gallery Artist unknown, *Reconstruction of the Mithraeum*, ca. 240 AD, painted plaster, 162.5 × 206.4 cm, Yale University Art Gallery, 1935.100 (Courtesy of Yale University Art Gallery)
the finishing touches to the gallery walls and fills around the wall paintings. Visitors can enter the altar to view the paintings and reliefs.

7. RECONSTRUCTION OF TWO CONNECTICUT PERIOD ROOMS

The same off-site conservation facility at Yale’s West Campus was used for the reconstruction of two rooms from 18th-century houses: one from Gilead, Connecticut, and the other from Branford, Connecticut. Though the Art Gallery purchased the Gilead Room in 1930, it has not been exhibited until now. The first phase of its treatment was an anoxic, five-week fumigation using argon gas in Marvelseal envelopes (fig. 11).

A team of contract furniture conservators—Melissa Carr, Tad Fallon, Randy Wilkinson, and Christine Thompson—and art handlers closely collaborated with Patricia E. Kane, the Friends of American Arts Curator of American Decorative Arts, on this project. Paint analysis, dendrochronology, major cleaning, and reconstruction were carried out for the Gilead Room. The Branford Room had been previously installed at the Art Gallery, but it was also reassembled at West Campus to correct past mistakes and streamline the reinstallation processes (fig. 12).

Like the mithraeum, the rooms were assembled on modular wood framing structures, using minimally invasive techniques and allowing them to be dismantled for transport and reinstallation in very tight exhibition spaces. Inpainting of losses for the Gilead Room was done with acrylic paints. The Branford Room’s painted walls had been partially stripped in the past so washes of gouache paints and

Fig. 11. Fumigation with argon of architectural elements including the Gilead Room (Courtesy of Yale University Art Gallery)
dry pigments were used to reintegrate the surfaces. The curators chose to present the historic rooms as objects or artifacts, with many layers of paint evident, rather than displaying them as freshly renovated rooms full of furniture and objects as if the occupants had just stepped out (figs. 13, 14). Visitors can walk across the creaking old floors and experience the space within the rooms.

8. PASTICHE OF CARVED INDIAN WOODWORK

The Art Gallery recently acquired a group of architectural elements from the ca. 1890 renovations designed by Lockwood de Forest for William Henry Appleton’s Wave Hill House in the Bronx. Carved from teak by the Ahmedabad (India) Wood Carving Workshop, the woodwork also dates to the late 19th century. The pieces, which were from an arched screen for a wide doorway, had previously been reconfigured as doors and various other architectural details. Unable to bring Indian wood carvers to New Haven, the curators consulted conservators, restorers, and local carvers about making new pieces to assemble with original components to reconstruct the screen. Once again, 3D scanners and the CNC machine were used to carve the missing pieces out of teak, leaving a fine-lined textured surface. The effect is similar to the fine parallel lines used in the tratteggio technique of inpainting and serves to distinguish the new pieces from the original pieces. Art handlers were trained to clean the old teak and woodworkers fabricated supports for the archway, again using a modular system.
Fig. 13. Gilead Room installed with a selection of decorative arts objects and reproduction painted floorcloth (Courtesy of Yale University Art Gallery)

Fig. 14. Branford Room receiving final installation touches (Courtesy of Yale University Art Gallery)
The archway was dismantled and reassembled in the Art Gallery. The new sections of teak were toned with washes of acrylic paints. The archway serves as a dramatic transition between a hallway with a sleek, new glass elevator and a gallery of late 19th- and early 20th-century furniture and decorative arts with ceiling paintings from the ca. 1890 Huntington Mansion (figs. 15, 16).

9. STAINED GLASS INSTALLATION CHALLENGE

On another side of the new glass elevator, an additional installation challenge was presented. A recently acquired 190-in. tall John LaFarge ca. 1900 stained glass window, The Good Knight, arrived at the Art Gallery restored but with all of its structural framework and supporting crossbars missing. Each of the
five panels that comprise the window, some with multiple layers of glass, lacked structural integrity. The window was to be installed on an interior 24-in. thick wall at the landing of glass stairs with a 16-ft. (192 in.) ceiling height, providing only a 2-in. clearance. Silver and jewelry were to be installed on the other side of this interior wall.

Collaborating with Metropolitan Museum of Art stained glass conservator, Drew Anderson, highly skilled museum technicians and fabricators designed and implemented a structural steel mounting system. Working from the top down, each panel was supported by a separate crossbar so as not to put weight on the panel below it. Steel rods were placed across the fronts of the panels for additional support, as they had been when the stained glass window was in a church. The rods were inserted into holes on the side exterior steel framework and attached with copper wire soldered to the lead came and twisted to tighten around the rod.

Lighting designer Steve Heffernan chose an acrylic sheet diffuser and LEDs that could be installed in the small space behind the stained glass window for even light with balanced color and minimal heat. A series of panels made from laminates run up a track system inside the wall. The panels
are hinged together so they can be raised and lowered like a garage door. This allows access to the lighting system through a nearly invisible lower panel on the wall in the American silver and jewelry gallery (figs. 17, 18).

10. FLOOR MOSAIC ON THE WALL

Another challenging wall installation was the mounting of a floor mosaic. Known as a city mosaic for its isometric representations of the cities of Memphis and Alexandria, the Byzantine mosaic was excavated in 1932 by the Yale University-British School in Jerusalem from the ca. 540 AD Church of Saints Peter and...
Paul at the Jordanian site of Gerasa (fig. 19). Upon its arrival at Yale, the approximately 13 × 20 ft. limestone mosaic was divided into five separate panels and backed first with plaster and then with steel reinforced concrete—a fairly standard procedure at the time. Over time, the mosaic panels suffered in storage from serious, multidirectional, structural cracking of both the concrete and ancient mosaic, aggravated by corrosion of the steel grid infrastructure. For its 2012 reinstallation, the decision was made to hang the mosaic on a masonry wall with minimal filling and reconstruction. A team of engineers, fabricators, collections managers, scientists, designers, art handlers, conservators, and curators collaborated on a strategy to replace the heavy, deteriorated concrete backings with new, lightweight composite materials used by aerospace, marine, and wind energy industries. Part way through the treatment, a loan request to borrow the mosaic for exhibition at the Metropolitan Museum of Art was approved, adding more criteria for development of the treatment strategy.

Fig. 18. The wall has a panel below the cases for accessing the LEDs (Courtesy of Yale University Art Gallery)
Surfaces were cleaned with a combination of steam and solvents to remove layers of dirt, animal glue, and aged linseed oil. Acrylic and glass microballoon mixtures were injected in cracks to create nonstructural fills. Following the application of a protective acrylic coating, each panel was faced with washed cotton muslin and hide glue. The panels were then placed face down on a cushioned torsion box designed and fabricated by our art handlers. The panel was lifted onto a custom-built 9 × 10 ft. bed for CNC dry milling to remove the concrete. A five horsepower motor and diamond router bits were used in various cutting patterns with software hand rendered to avoid hitting steel crossbars. The milling stopped precisely at the plaster layer, 1–2 mm from the backs of the limestone tesserae. Heat dissipation during the dry milling was improved by adequate dust extraction and a vortex tube spot cooler. After considerable preliminary trial and error, the milling process was refined to remove concrete from an 8 × 9 ft. panel in two weeks. The CNC machine needed to be monitored but other work could be done simultaneously in the same room while the concrete was removed. One round of milling removed the concrete, allowing the steel frames to be extricated; a final pass of milling provided the 1930s plaster remaining on the back of the mosaic with a level surface and a good texture for bonding. The setup and process are illustrated in figures 20 and 21.

After researching and testing various materials and methods used by other museums (Uprichard et al. 2000) as well as laminates of glass, carbon, and Kevlar fiber cloths, new lightweight composite materials were chosen for the backing panels. Because the mosaic would be hung on a masonry wall that receives direct sunlight in the winter months, our engineer was concerned about closely matching the coefficients of thermal expansion as well as about good bond and shear strength of adhesives used to attach the backing panels. An additional concern was that if this treatment were to be used as a model by others, the materials chosen would need to be available around the Mediterranean, where so many ancient mosaics previously backed with reinforced concrete are actively disintegrating and in urgent need
of replacement. Composite panels were fabricated using a closed-cell structural polyester foam core faced on both sides with fiberglass and polyester resin, materials that are available wherever there is a boat building industry. Stainless steel threaded anchors were inserted into the polyester foam during manufacture of the panels, strategically placed to serve as attachment points for the hanging system hardware (fig. 22).

For the backing procedure, the exposed plaster was consolidated with acrylic resin, and nonstructural fills in cracks on the reverse were done, again by injecting acrylic and glass microballoon mixtures. A layer of fiberglass and epoxy was applied overall, followed by a layer of the same epoxy bulked with fumed silica. The composite panels were put in place and weighted while the epoxy was fully cured. In most methods used for vertical installation of mosaics, epoxy is chosen for its strength even though its aging characteristics and irreversibility are causes for concern. However, tests showed that the CNC milling will easily and precisely remove the epoxy, thus reversibility becomes less of an issue.

Losses that were present at the time of excavation and all edges were filled and coated with a mixture of clean sand and aqueous acrylic paste. For losses between the panels, which were to be joined with compression bolts from the reverse, 4-lb. Ethafoam was carved and painted with acrylics to match the ancient tesserae. Archival photographs showed what had been lost and were used to guide these reconstructions.
Fig. 21. Colombo motor, cooling and dust extraction during milling (Courtesy of Yale University Art Gallery)

Fig. 22. Schematic of mosaic with fiberglass, epoxy, and new composite panel (Courtesy of Yale University Art Gallery)
A 3 × 3 in. tubular aluminum framework was welded together by art fabricators and attached with screws to the embedded anchors in the composite panel backings (fig. 23). The framework provided a pin and bolt system to join the panels as well as brackets for lowering onto aluminum cleats bolted into the masonry mortar on the walls. This system was designed to allow the framework to be hung temporarily on the wall to ensure good alignment, then be detached from the wall and attached to the backs of the panels. For installation, a forklift was used to support the panels, with two scissor lifts on either side for art handlers to guide the panels into place. The Gerasa city mosaic was successfully installed for the Metropolitan Museum of Art exhibition, *Byzantium and Islam: Age of Transition*, and then installed in the Art of the Ancient Mediterranean Gallery at the Yale University Art Gallery (fig. 24). The weight of the mosaic before treatment was over 5,000 lb. and after treatment it was just under 1,300 lb. Such an accomplishment was possible through the innovative ideas and collaborative approach of a team of Art Gallery staff and outside consultants and contractors.

11. CONCLUSION

Rather than a source of stress, renovations can be a source of inspiration. Initiated by director Jock Reynolds, the building renovations provided great opportunities to pursue new materials and treatments through research and development. The renovations and conservation were supported by generous patrons who believed in the larger vision of a reunited university museum to fulfill the Art Gallery’s mission “to encourage appreciation and understanding of art and its role in society through direct engagement with original works of art” (The Yale University Art Gallery 2014).
These case studies represent a small percentage of the many projects undertaken by the Conservation Department during the renovations. Divisions among departments melted away as new collaborative teams formed in response to the challenging schedule and expanded exhibition spaces. Most of the 10 case studies described here were carried out at Yale’s West Campus, a former Bayer pharmaceutical facility purchased by the university in 2007. The Art Gallery has access to over 50,000 square ft. of multiuse space allowing such innovative work to be done.

Looking ahead, we are already applying new developments in 3D scanning and other imaging techniques, 3D printing in plastics and metals, and advances in scientific analysis made possible by new facilities at Yale: the Center for Engineering Innovation and Design, the Digital Collections Center, and the Institute for the Preservation of Cultural Heritage.

Appendix 1. LIST OF WORKS OF ART

1974.86

Lipstick (Ascending) on Caterpillar Tracks
Artist: Claes Oldenburg, American, born Sweden 1929, BA 1950, B.F.A. 1951
American, 20th century, 1969, reworked in 1974
Painted steel, aluminum, and fiberglass
670.6 × 594.4 × 332.7 cm (264 × 234 × 131 in.)
Gift of the Colossal Keepsake Corporation
1993.72.1

**Unit BOLUS—Wad in, CONDITION, Wad out. (disciplinary funnel)**

*Unit Bolus*

American, 20th century, 1991
Cast petroleum jelly 8-lb. dumbbell, stainless steel, and electronic freezing device
71.1 × 45.7 × 25.4 cm (28 × 18 × 10 in.)
Gift of Robert F. and Anna Marie Shapiro edition 5/5

1941.446a-c

**Rotary Glass Plates (Precision Optics) formerly titled as, Revolving Glass Machine**

*Appareil Rotatif (Optique de Precision)*

*Rotative Plaque Verre (Optique de Precision)*

Artist Marcel Duchamp, American, born France, 1887–1968
French, 20th century, 1920
Painted glass, iron, electric motor, and mixed media (largest blade damaged in 2007 and replaced by facsimile in 2011)
165.7 × 157.5 × 96.5 cm (65 1/4 × 62 × 38 in.)
Gift of Collection Société Anonyme

ILE2006.4.384

**Pennant**

Maker Unknown
Indonesia, East Sumba, ca. 1900 or earlier
Beads and imported cotton cloth; appliqué
58 × 34 cm (22 13/16 × 13 3/8 in.)
*Made in*: Sumba, Indonesia
Promised gift of Thomas Jaffe, BA 1971

ILE2006.4.385

**Pattern Guide (Pahudu)**

Maker Unknown
Indonesia, East Sumba, mid 20th century
Bamboo and cotton
65 × 44 cm (25 9/16 × 17 5/16 in.)
*Made in*: Sumba, Indonesia
Promised gift of Thomas Jaffe, BA 1971

ILE2006.4.391

**Woman's Ceremonial Skirt (Hinggi, Lau Pahudu)**

Maker Unknown
Indonesia, Sumba, Kanatang, 19th century
Cotton, supplementary warp, daubing
59 × 135 cm (23 1/4 × 53 1/8in.)
*Made in*: Kanatang, Sumba, Indonesia
Promised gift of Thomas Jaffe, BA 1971
ILE2006.4.394

**Man’s Mantle or Hipcloth (Hinggi)**

Maker Unknown  
Indonesia, Sumba, Kapunduk, late 19th century  
Handspun cotton, warp ikat, daubing, twining  
Object: 222 × 138 cm (87 3/8 × 54 5/16 in.)  
*Made in:* Kapunduk, Sumba, Indonesia  
Promised gift of Thomas Jaffe, BA 1971

1933.680

**Iron Horse Armor**

Maker Unknown  
Syrian, Dura-Europos, Roman, second or third century AD, ca. AD 165–256  
Iron, linen, rawhide, and leather  
Overall (Flat): 130.81 × 177.8 cm (51 1/2 × 70 in.)  
Yale-French Excavations at Dura-Europos, Tower 19

1935.100

**Reconstruction of the Mithraeum**

Artist: Unknown  
Syrian, Dura-Europos, Roman, third century AD, ca. 240 AD  
Painted plaster  
162.5 × 206.4 cm (64 × 81 1/4 in.)  
Yale-French Excavations at Dura-Europos

1930.5058

**Gilead parlor room**

Maker Unknown  
American, 1770–71  
White pine and paint  
*Made in:* Hebron, now Gilead, Connecticut  
Mabel Brady Garvan Collection

1926.114

**North Branford Living Room**

*Rose Curtiss House*  
Maker Unknown  
American, 18th century, 1750–1775  
Eastern white pine; yellow poplar  
*Made in:* North Branford, Connecticut  
*Made in:* New Haven County  
Mabel Brady Garvan Collection
2008.137

A group of carved architectural elements from the Appleton House, Bronx, New York
Designer Lockwood de Forest, American, 1850–1932
Manufacturer Ahmedabad Wood Carving Workshop, 1881–1907
Indian, 19th century, ca. 1891
Teak
Made in: Ahmedabad, India
Designed in: New York, New York
Owned in: Bronx, New York
Leonard C. Hanna Jr., Class of 1913, Fund

2009.162.1

The Good Knight
Designer John La Farge, American, 1835–1910
Honorand Albert Grenville Boynton, American, 1837–1898
American, 19th century, Designed 1899, dedicated 1903
Leaded glass
482.601 × 142.24 cm (190 × 56 in.)
Made in: New York, New York
Owned in: Detroit, Michigan
Purchased with the Leonard C. Hanna Jr., Class of 1913, Fund, and a gift from Alison and William Vareika in honor of Jean and David W. Wallace, B.S. 1948

1932.1735

Mosaic floor depicting the cities of Alexandria and Memphis
Jordanian, Gerasa, Early Christian, ca. AD 540
Mosaic: limestone tesserae
396.25 × 609.6 cm (156 × 240 in.)
The Yale-British School Excavations at Gerasa

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**SOURCES OF MATERIALS AND SERVICES**

**Claes Oldenburg’s Lipstick (Ascending) on Caterpillar Tracks:**

Carboline CZ11 Carbozinc; Carboline Carboguard 890, color Walnut Grove 2248

[www.carboline.com](http://www.carboline.com)

DuPont epoxy primer; DuPont Imron full gloss gold custom color #43484X; DuPont ChromaSystem orange base coat custom color #31KM and full gloss clear top coat Chroma #725005

[http://pc.dupont.com](http://pc.dupont.com)

New England Boatworks

[www.neboatworks.com](http://www.neboatworks.com)

Tnemec F. C. Typoxy Series 27 black epoxy primer; Tnemec semi-gloss black Endura-Shield II 1075 Aliphatic Acrylic Polyurethane

[www.tnemec.com](http://www.tnemec.com)

Welding Works

[www.weldingworks.com](http://www.weldingworks.com)

**Matthew Barney’s Unit BOLUS—Wad in, CONDITION, Wad out. (disciplinary funnel):**

Dow Corning Silicone GI 1000 platinum Cure

Silicone & Epoxy Technology

West Babylon, NY

Petroleum jelly composition available from the artist

**DuChamp’s Rotary Glass Plates (Precision Optics):**

Depp Glass

[www.deppglass.com](http://www.deppglass.com)

Golden acrylic paints

[www.jerrysartarama.com](http://www.jerrysartarama.com)

**Model of DuChamp’s Rotary Glass Plates (Precision Optics):**

The Hubb Consolidated, Inc.

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**Textile rotations:**

Flannel and adhesive backed ultra suede

[www.benchmarkcatalog.com](http://www.benchmarkcatalog.com)
Panels
SmallCorp Products for the Display, Conservation, and Storage of Works of Art, Textiles and Objects
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**John La Farge stained glass The Good Knight:**
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Diffuser: Acrylite FF crystal ice 0M001 (0917.8)
www.acrylite.net

Optolum white LED panels
www.optolum.com

**Gerasa city mosaic:**
- 1-methyl-2-pyrrolidinone
  www.chem.yale.edu/res/chemstockroom.html

CNC table
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www.corematerials.3Acomposites.com

Stainless steel inserts
www.rotaloc.com

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www.compositepanelsolutions.com

West system 105 epoxy, 205 hardener, and fiberglass
www.jamestowndistributors.com

Fabricators of aluminum framework
www.artfabricators.com

Future projects:
Center for Engineering Innovation and Design
http://ceid.yale.edu

Yale Institute for the Preservation of Cultural Heritage: IPCH Technical Studies Lab, IPCH Aging Diagnostics Lab, IPCH Digitization Lab, IPCH Conservation Lab
http://ipch.yale.edu/about-ipch

CAROL SNOW joined the staff of the Yale University Art Gallery Conservation Department in 2008 as the first full-time objects conservator. In 2012, she was promoted to the position of deputy chief conservator and in 2013 she was named the Alan J. Dworsky Senior Conservator of Objects. She is responsible for the conservation and preservation of an encyclopedic collection spanning from ancient to contemporary three-dimensional works of art in a wide range of media, including stone, metals, ceramics, glass, wood, ivory, textiles, plastics, and electronic media. Future plans for the Yale University Art Gallery Conservation Department involve renovation of spaces on Yale’s West Campus to become a part of the Center for Conservation and Preservation and to collaborate with the Digital Collections Center and the Institute for the Preservation of Cultural Heritage. Address: Yale University Art Gallery, 341 Crown St., New Haven, CT 06511-5405. E-mail: carol.snow@yale.edu