

Great Pagoda, Kew, Returns to 18th Century Glory with Help from 3D Systems

3D Systems On Demand Manufacturing experts help restore UNESCO World Heritage Site with scan-to-CAD workflow and SLS printing

Restoration is a major undertaking. Beyond the painstaking care essential to preserve and stabilize historical structures, restoration includes lots of research and planning to return relics to a known or assumed state with as much integrity as possible.

When the Historic Royal Palaces (HRP) in the United Kingdom began its undertaking to restore The Great Pagoda, Kew, it faced some monumental challenges. Several key design elements from the original building had been lost to history, and replacing them quickly proved challenging in terms of cost, logistics and design. Yet by bringing the technologies and expertise of 3D Systems On Demand Manufacturing to this project, this effort was made not only manageable, but efficient.

CHALLENGE:

Replace full suite of ornately carved dragons missing from a UNESCO World Heritage Site for over 200 years.

SOLUTION:

3D Systems On Demand Manufacturing services deliver 72 lightweight and durable dragons using a scan-to-CAD workflow with Geomagic software, selective laser sintering (SLS) printing and high quality finishing.

RESULTS:

- Lightweight design and construction to alleviate concerns of overloading aged structure
- Digital scan-to-CAD workflow matched with SLS 3D printing removes cost and delay of unique tooling for each dragon
- Interior dragon design enables easy installation with no visible trace of construction
- Outcome reconciles customer's aesthetic requirements with technical requirements of the builders



After 3D printing, the dragons were finished and hand painted by 3D Systems' High Wycombe finishing department.



The new dragons were hand painted by 3D Systems High Wycombe finishing department.

Using a scan-to-CAD workflow with selective laser sintering (SLS) additive manufacturing, 3D Systems On Demand Manufacturing team delivered durable and repeatable fixtures for HRP's restoration effort. Far from a hands-off process, the team contributed many hours of frontend engineering and backend finishing to provide high quality full-service design and manufacturing expertise.

A UNESCO World Heritage Site

Though popular opinion of King George III may be divided, there is no denying the impact of his 59-year reign. Beyond the countless volumes of extensive studies and films on his life and rule, his legacy is steeped into the very earth of the lands he governed — particularly at The Royal Botanic Gardens, Kew. A UNESCO World Heritage Site, the gardens are home to The Great Pagoda, a striking 163-foot structure commissioned in 1761 and built in ornate and highly fashionable Chinoiserie style.

In the years following the pagoda's unveiling, it drew crowds of tourists who came to marvel at its exotic and eye-catching details. Central to all conversations were the 80 painted wooden dragons that adorned the octagonal corners of each successive level.

The talk of the town for more than twenty years, the Kew dragons were removed in the 1780s to accommodate roof repairs to the pagoda and were never replaced. Although rumors allege the dragons served as payment for royal gambling debts, experts believe the wood had simply rotted over time. An often revisited topic for conservationists, The Great Pagoda is finally being returned to its former splendor, dragons and all, for the first time in over 200 years. As part of a restoration project undertaken by HRP and the Royal Botanic Gardens, Kew, this batch of dragons is designed to stand the test of time with special reinforcement by modern technology.

Quality fit for a king

As HRP began to explore methodologies for replacing the dragons, it faced a dilemma: not only would wooden replacements invite the same longevity issue as before, but the pagoda had not supported the weight of the dragons for two centuries. "One of the most challenging aspects of this project was to minimize the impact imposed by so many dragons on this grade one listed building," said Craig Hatto, Project Director at Historic Royal Palaces. Concerned that the aged structure may respond poorly to the sudden reintroduction of 80 full-weight, large-scale ornaments, HRP wanted to explore a lighter-weight alternative to help guarantee a successful and incident-free installation. Paired with these practical considerations were the equally valid issues of the time and costs associated with traditional materials and processes.

HRP was looking for a restoration solution that would answer the quality, weight, time and cost concerns inherent to the project. In searching for a supplier capable of delivering on all aspects, HRP asked 3D Systems to submit a competitive tender, which it subsequently won on the basis of being able to provide the expertise, technology, quality and scalability required to fulfill the project.

Designing the dragons

The Kew dragons were brought to life as a collaborative effort between two sets of specialized designers. The exterior appearance of the dragons was recreated by HRP using the scarce historical information available to achieve the most accurate representation possible. Once designed, a dragon prototype was carved from wood to enable the digital manufacturing workflow that followed, undertaken by the second design and engineering team at 3D Systems. Seven additional wooden dragons were carved to adorn the first level of the pagoda, leaving 72 to be created using SLS printing.

Using a reverse engineering workflow and a FARO® Design ScanArm, the carved wooden dragon was scanned into a 3D design environment that would allow 3D Systems to address HRP's concerns regarding weight. 3D Systems' design experts used a variety of software including Geomagic® Design X™ to reverse engineer the scan data into CAD and hollow the scan data to a controlled thickness, preserving both the exterior details and structural integrity in the process.

When combined with the intricate exteriors of the hand cut masters, the resulting hollow geometry was too complex to be manufactured traditionally and required additive manufacturing for production. Using a digital manufacturing workflow also enabled 3D Systems to seamlessly scale the dragons to achieve a slightly different size for levels two through ten of the pagoda. In total, 18 designs were prepared, comprised of nine different dragon sizes and a left- and right-hand version of each.

3D Systems' engineers incorporated another simple yet compelling feature into each of dragon designs by adding built-in mounting features directly into the CAD files. These designs constituted part of the dragons' construction designs, and were devised and implemented by 3D Systems' On Demand Manufacturing team in close collaboration with Hockley & Dawson, the other lead engineering team on the project. Due to the mechanics required for reinforcement and mounting, each of the 18 dragon variations required individual attention and design work.

"The final dragons are essentially a perfect copy of the original, but have been improved upon in a way that is invisible to the observer," said Nick Lewis, General Manager UK, 3D Systems On Demand Manufacturing. "We engineered internal elements for a secure mounting process, but

designed them in such a way as to be completely concealed so no nuts, bolts or traces of construction will be visible."

Hidden benefits of additive manufacturing

Taking advantage of the ability to design for additive manufacturing, 3D Systems' On Demand Manufacturing team incorporated a series of screws, threads and covers that follow the exact form of the dragons along the spine. "The final structures we delivered take advantage of the unique value that can be extracted from the additive process," said Lewis. "Engineering in this way is common practice for us, but it is still miraculous to our customers. The wow-factor makes it fun to reveal, but to me it's about being resourceful and solving problems more effectively and efficiently, which is a central benefit of using our technology."

3D Systems' engineering expertise is built into each of the 18 different versions of the dragons that were SLS printed. As 3D Systems On Demand Manufacturing Regional Sales Manager Simon Hammond points out, the ability to match precision with variety is a consistent benefit of using additive manufacturing for production. "Many hours of careful engineering work were put into the final designs, but by using a digital workflow with 3D CAD and 3D printing, we are able to frontload the time investment," Hammond says. "Once final files were ready, we could launch into production with 18 different outcomes without 18 sets of tooling and molds. Designing and manufacturing the same outcome with good cost and sensible timing would be challenging for any other process."

Following 3D scanning and design, early prototypes of the dragons were printed for analysis and testing to ensure the final designs were built in accordance with the stringent requirements of modern construction.



The carved wooden dragon was 3D scanned as part of a reverse engineering workflow.



The final dragons ranged in size from 1.2 - 2 meters.



SLS 3D printing solved the quality, weight, time and cost concerns of the HRP restoration team.

Throughout this process, 3D Systems worked diligently to deliver on the customer's aesthetic requirements while meeting all the technical requirements of the builders. These considerations came into play as 3D Systems' engineers determined how to best divide the SLS model for printing as well as position and conceal the various caps and closures for mounting.

Production 3D printing for historical restoration

3D Systems' On Demand Manufacturing teams in the UK and the Netherlands printed the dragons using SLS technology. Due to the large scale of the dragons, each with final dimensions in the 1.2 – 2 meter range, 3D Systems sPro® 230 SLS machines were chosen for the task. With a maximum build volume of 550 mm x 550 mm x 750 mm, the sPro 230 enabled the dragons to be produced in a low number of large pieces that were expertly assembled by the 3D Systems team.

The dragons were 3D printed in DuraForm® PA, a durable polyamide 12 nylon material capable of producing a comparable look and feel to the original dragons. The resolution and mechanical properties of DuraForm PA make it an ideal candidate for complex parts with thin walls or snap fit requirements. In the case of the Kew dragons, these features suited both the functionality requirement of installation as well as the cosmetic requirements of the historic restoration. Once printed, the dragons were finished and hand painted in the UK by the 3D Systems High Wycombe finishing department. 3D Systems' team also painted the final wooden dragons to ensure visual consistency across the project.



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"3D Systems is greatly honored to have been selected for this project," said Lewis. "In addition to the rare opportunity to help restore a cultural and historical landmark, this project showcases the extreme element of what we do. Our expertise extends far beyond 3D printing and we were able to offer guidance across multiple stages of this restoration, from engineering and scalable production through to finishing."

The big reveal

After standing for 200 years without its proper ornamentation, The Great Pagoda, Kew, will finally be restored to draw curious crowds once more. "Over the decades, many have tried and failed to recreate the lost dragons at Kew, which has now only become possible through the innovative use of 3D printing," says Hatto. "The specialist team developed an innovative, lightweight and durable solution, which has ultimately allowed us to return these lost icons to this treasured royal building. The dragons can take their rightful place within this UNESCO World Heritage Site and once again be part of the London skyline for many years to come."

Whether you are seeking full reverse engineering and low volume manufacturing services or need fast turn 3D printed parts, advanced prototyping or appearance models, 3D Systems On Demand Manufacturing can help. Technologies include a broad array of 3D printing technology and finishing expertise as well as conventional CNC, urethane casting and injection tooling.

Contact 3D Systems' experts for more information.



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