White Paper

Acoustic Modeling in Historical Research: Developing Open-Source Software for Exploring the Sounds of Worship and City Life at St Paul’s Cathedral, London, in 1622

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St Paul’s Cathedral, the East Front. From the Visual Model, rendered by Austin Corrher

Submitted by: John N. Wall, David Hill, and Yun Jing – Principal Investigators
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1. Project Summary

The Virtual St Paul’s Cathedral Project set out to demonstrate the capabilities of visual and acoustic digital modeling to recreate the sights and sounds of past events so that they could be experienced unfolding in real time. The site for recreating past events was to be St Paul’s Cathedral in London in the early 17th century and its surrounding Churchyard. We also sought to make the tools for digital acoustic modeling available to a wider audience by developing an open-source acoustic modeling package and to demonstrate its capabilities in our acoustic modeling. The results of our work are now available on the Project’s website: https://vpcathedral.chass.ncsu.edu/.

The digital modeling tools we have developed and employed enable us to integrate the physical traces of preFire St Paul’s Cathedral with the surviving visual record of the cathedral and its surroundings to create a visual model of the Cathedral and its churchyard. They also enable us to experience a historically faithful interpretation of worship inside the Cathedral as well as the preaching styles of Lancelot Andrewes and John Donne, based on contemporary descriptions of early modern preachers’ capacity to engage their congregations imaginatively and emotionally and to delight them with their wit.

*St Paul’s Cathedral, the West Front.* From the Visual Model, rendered by Austin Corriher.

In accord with the methodological principles for developing computer-based visualizations (and
now auralizations) of historically significant cultural sites set forth in the London Charter for the Computer-based Visualisation of Cultural Heritage, the Virtual Paul’s Cross Project is defined as a “evidence-based restoration” of the north east end of Paul’s Churchyard in November of 1622.

Following the Charter’s concern for the importance of intellectual transparency in computer-based modeling and visualization of historic sites, the Virtual St Paul’s Cathedral Project, together with its companion Virtual Paul’s Cross Project, lists all research sources and seeks to clarify how the various kinds of historic materials came together to make possible what one sees and hears on this site.

![St Paul’s Cathedral, the Tower. From the Visual Model, rendered by Austin Corriher.](image)

This includes discussions of sources for all the elements of what one sees and hears on this site, as well as assessment of the relative values of different kinds of evidence. In addition, clear distinctions are made between those aspects of the site that

1. represent historic information, or
2. offer representative approximations of lost structures, or
3. recreate lost experiences.

In the case of the latter of these aspects of the Virtual Paul’s Cross Project, the grounds for belief in the (extent of the) accuracy of approximations or recreations, as well as careful presentation of the assumptions guiding their development and realization are extensively delineated.

**We are pleased to report that we have fully met or exceeded all of our three original goals.**

**Goal 1.** To develop an open-source acoustic modeling software package to enable anyone to explore the acoustic properties of historic sites without needing to invest the significant cost of
proprietary commercial software packages.

**Progress to Date:** Dr Jing, his graduate student Julian Elo, and other students under his supervision have completed their development of our open-source acoustic modeling program, called iPack-Simpa, based on the existing I-Simpa program. They have also drafted an instructional manual to enable its use. The files for this program, along with the manual, have been added to the website, and are available here (go to [https://vpcathedral.chass.ncsu.edu/](https://vpcathedral.chass.ncsu.edu/) then click on the iPack-Simpa tab under the heading “Acoustic Model.”

**Status: Goal 1 -- 100% Completed.**

![](image)

*St Paul’s Cathedral, the West Front. From the Visual Model, rendered by Austin Corriner.*

**Goal 2.** To demonstrate the capabilities of our software package by recreating worship services and sermons staged inside the cathedral, to complement our recreation of John Donne’s sermon for November 22, 1622 as part of our *Virtual Paul’s Cross Project*.

**Progress to Date:** Recordings made and organized; files edited and complied, auralization completed, sound files installed on the Project’s website.

**Status: Goal 2 -- 100% Completed**

**Goal 3.** To set these worship recreations inside an expanded visual model, incorporating the visual model of Paul’s Churchyard from the earlier project into a much larger model including the entire cathedral, both inside and out, and the remainder of the structures and passageways in Paul’s Churchyard.
Progress to Date: David Hill and his present and former students have completed the basic visual models; they have also completed various modes of display, included still images, panoramic views, an animated fly-around video, and a VR installation, all installed on the project’s website. They have also undertaken a thorough revision of our website.

Status: Goal 3 – 100% Completed

2. Project Origins and Goals

Beginnings

The Virtual St Paul’s Cathedral Project grew out of my conviction that the post-Reformation Church of England represented an effort to create a truly national church that was pragmatic, corporate, liturgical, and sacramental. While the people who created it were surely influenced by continental reformers, the English were not dominated by their European colleagues. Instead, they were engaged in a reformation of the Medieval Church that pragmatically addressed distinctively English needs and concerns. While they retained from the Medieval Church what they found valuable and useful, they changed those things they believed got in the way of their vision of a nation united as a godly kingdom. Enabled by the Book of Common Prayer, they sought participation in the Christian life through corporate reading of the Bible, offering their prayers to God, intending to lead a new life, and finding in unity with Christ at Communion their identity with Christ’s “mystical Body” and on the way to becoming a true Christian commonwealth.

Sundays in cathedrals and collegiate and parish churches saw the people of God gathered for Morning Prayer, the Great Litany, and Holy Communion with sermon, followed in the
afternoon by Evening Prayer, perhaps including catechizing or another sermon. Each weekday, clergy, either alone or with members of their flocks, continued the reading of Morning and Evening Prayer.

From this perspective, the clearest expression of the kind of Church the Church of England actually was is embodied in the corporate worship practiced in cathedrals and in collegiate and local parish churches. The Book of Common Prayer replaced medieval language that affirmed Christ’s material presence in the Mass by language that celebrated Christ’s spiritual presence in the assembled congregation, the Body of Christ for the Body of Christ.

The Prayer Book’s Lectionary brought the Bible into the daily lives of Englishfolk in a structured way, causing the Book of Psalms to be read once a month; the New Testament, 3 times a year; and the Old Testament, once a year, within the daily and weekly round of worship services and the passage of the seasons of the Church Year. People were born and baptized, in church; they were married, in church; they participated in the rites of the Prayer Book, in church; they confessed and were absolved, they received the bread and wine of communion, in church; their children were born and baptized, in church; when they died, their lives were remembered and their faith proclaimed, in church.

The practice of public worship thus created a corporate environment of hearing, of learning and interpreting, of grounding the private and individual in the lived experience of the public and corporate. So we set out to demonstrate that the tools of visual and acoustic modeling would enable us to experience this style of worship and preaching at St Paul’s Cathedral as events that unfold over time and on particular occasions in London in the early seventeenth century.
Audience

The audience for our Project is primarily academic, although the fascination of experiencing historical events through their authentic recreations in the spaces in which those events originally took place has turned out to engage a wider audience. The public unveiling of an installation of the Virtual Paul’s Cross Project made the front page of our local newspaper.

Nonetheless, our primary goal has been to engage the conversation about the English Reformation from the perspective of the experience of corporate worship choreographed by the Book of Common Prayer. Past conversations about the Church of England post-Reformation have been based primarily on assumptions that emphasize the importance of the theological conversation, seeking to identify which Continental theological voices were most influential on Thomas Cranmer and the other English reformers. This approach now seems problematic, since we find that the English Reformers were more concerned with the public life of the Church as gathered community than with specific doctrinal confessions; the Church of England affirmed the faith of the historic Creeds recited in the context of public worship than in contemporary reformulations of the Faith.

Yet emphasis on theological formulations is more easily graspable than the daily and weekly practices of public worship. Even though we can know what biblical texts were read in public worship every day of the year, historians and scholars of the period’s literature only occasionally turn to that resource in their work. Now, thanks to the Virtual St Paul’s Cathedral Project, scholars and the interested public can explore how the worship practices of the gathered members of the Church of England provided the context, and the vehicle, for understanding Christian faith, developing religious identity, and practicing the vocabulary of belief.
Engaging the Profession

The Virtual St Paul’s Cathedral Project has drawn on the expertise of a truly multidisciplinary range of professional expertise. The subject matter of the Project is drawn from the disciplines of English literature, English history, Reformation Studies, the history of religions, music history, the history of performance styles, art history, archaeology, architectural history, the history of weather, and historical theology, among others. The process of creating the content of our work has drawn on the practices of architectural modeling, data visualization, acoustic modeling, acoustic engineering, visual representation, digital rendering and representation, among others. The ways in which words are spoken and sung, or instrumental music performed, draw on the history and practices of church music composition, liturgical performance, choral singing and organ performance, and historical linguistics (in the recreation of London spoken English), among others.

St Paul’s Cathedral, the Cross Yard. From the Visual Model, rendered by Austin Corriher.

The Foundations

The Proof-of-Concept project for the Cathedral Project was the Virtual Paul’s Cross Project, funded by a Digital Humanities Start-Up grant from the National Endowment for the Humanities. The Paul’s Cross Project pioneered the use of visual and acoustic modeling technologies to recreate past events in their original locales. The Project recreates a 2-hour-long sermon that John Donne delivered on November 5th, 1622, at the Paul’s Cross Preaching Station in the northeast corner of Paul’s Churchyard. One in a long series of sermons delivered at this site during the 16th and 17th centuries, Donne’s sermon celebrates King James I’s delivery from the original Gunpowder Plot of 1605 and defends James’ current efforts to curb popular unrest
over his plans for his son Charles to marry the very Catholic daughter of the King of Spain. The goals of the Paul’s Cross Project included helping us understand and evaluate our assumptions about the look and sound of the Paul’s Cross sermon, adding experience in real time to our repertory of tools for interpreting these events, and – because it is flexible and open to change – creating the opportunity for testing and evaluating multiple models of the event it recreates as new information and new interpretations emerge.

As a result of this project, we have become more fully aware that early modern sermons were participatory and collaborative, improvised from notes, and responsive to specific local conditions like random ambient noise, crowd size, and the specific conditions of the setting, including the weather and the bells of the cathedral clock. We are also more fully aware that the details of performance conditions can sometimes be glimpsed in the surviving texts of these sermons.

3. The Process

The Virtual St Paul’s Cathedral Project has been the work of a team of students and scholars, totaling at least a hundred people, over a period of six years. There are too many for all to be named here, and, indeed, some, like the managers of the recording studios in Cambridge and London, are unknown to us, but the most complete list can be found on the Project website.
here <https://vpcathedral.chass.ncsu.edu/?page_id=169>.

Organization, Personnel, Expertise

There have been three Co-Principal Investigators, all members of the faculty at NC State University

- John N. Wall, Professor of English in the College of Humanities and Social Sciences at NC State University, planned the project, applied for funding, coordinated the work, and created the website.
- David Hill, Professor of Architecture in the College of Design at NC State University, supervised graduate students in architecture who created the Visual Model, designed the project’s website, and created the fly-around video and the rendered images of the model.
- Yun Jing, formerly Associate Professor in the College of Engineering at NC State University, now Associate Professor in Acoustic Engineering at Penn State University, supervised undergraduate and graduate students in Engineering at NC State University in development of the I-Pack Simpa software and the process of auralizing sound files for use in the Project.

The work of the Project was performed by several teams of individuals, both in North Carolina and in England.

The Visual Modeling Team, supervised by David Hill, consisted, at the beginning, of graduate students in the Masters of Architecture program in the College of Design ad NC State University. Over time, some of these folks continued to work for us after they had graduated and begun their professional careers as architects.

St Paul’s Cathedral, the Chapter House. From the Visual Model, rendered by Austin Corriher.
Their work consisted of using historical evidence to create the visual models of the interior of the Cathedral and the exterior of the Cathedral and its surrounding Churchyard. They started with wireframe models, then added surfaces and colors, finally rendering images that incorporated age of the buildings, weather, and the angle of sunlight to the images. These folks played large roles and small, but chief among them were Joshua Stephens, Jordan Gray, Cameron Westbrook, Smith Marks, and Austin Corriher. Stephens and Caroline Cox created fly-around videos. Grey Isley worked on the basic model, then turned the Choir section of the Model into a Virtual Reality version. Trevor Healy developed the design for the Cathedral Project’s website.

Providing essential advice and counsel at every step of the way in the development of the Visual Models has been the distinguished architectural historian John Schofield, long-time member of the staff of the Museum of London Archaeology (MOLA), official archaeologist at St Paul’s Cathedral, author of St Paul’s Cathedral Before Wren (2011) and a host of other books and articles on the official and domestic architecture of medieval and early modern London.

Under Dr Schofield’s supervision, several pieces of the Visual Model, including some of the most complex parts, were contributed by folks on the staff of MOLA, including the Great Rose Window (Mark Samuel), the main parts of the walls and vaulting (Carlos Lemos), funeral monuments (Juan Jose Fuldain), the choir stalls (Hannah Faux and John Schofield), and the bishop’s throne and lectern by John Schofield.

The Acoustic Modeling Team, supervised by Yun Jing, consisted initially of Dr Jing’s graduate students in Engineering, especially Julius Elo, who created the I-Pack Simpa program and wrote its user’s manual. It was later joined by Seth Hollandsworth, an undergraduate student in computer science and mechanical engineering at NC State University, who carried out the auralization process for the sound files.
The Sound Production Team consisted of scholars who chose musical scores and liturgical texts and produced original pronunciation scripts of them, of actors and musicians who performed the musical scores and the spoken-word scripts and of recording engineers and editors who supervised the recording sessions and edited the resulting files into recordings suitable for auralization.

Dr Wall compiled the original scripts for sermons and worship services. They were then translated into early modern London dialect by David Crystal, a distinguished linguist in England. Dr Crystal can also be heard delivering his script of Bo Andrewes’ Easter Day sermon as part of the Holy Communion service. The recording of Donne’s sermon for Easter Day 1624 was made by Ben Crystal, a professional actor from England. The parts of other clergy taking part in the services on Easter Day and the Tuesday after the First Sunday in Advent are performed by the British actors Colin Hurley and William Sutton.

The choice of musical scores for the performances was made by Dr Roger Bowers, Emeritus Reader in Medieval and Renaissance Music at Jesus College, Cambridge University, who has been invaluable to the acoustic dimension of the Virtual St Paul’s Cathedral Project from the very beginning. The performance of music in our recordings was by the Choir of Jesus College, under the direction of Richard Pinel, Choirmaster at Jesus College. Organ music in these recordings was played by Pinel or by Organ Scholars Dewi Rees and Jordan Wong.

Recording engineers for the sessions in Cambridge and London were Matthew Dilley and Daniel Halford. The editing of sound files was done by Neal Hutcheson, an Emmy Award-winning documentarian and filmmaker on the staff of the distinguished linguist Walt Wolfram, at NC
In addition, the staffs of Dr Thomas Birkland, Associate Dean for Research in the College of Humanities and Social Sciences at NC State University, and his counterparts in the Colleges of Design and Engineering, have all been exceptionally supportive and helpful.

The Advisory Committee

The Virtual St Paul’s Cathedral Project has been blessed from the beginning by an active and hard-working Advisory Committee whose members have provided guidance, raised questions, written letters of support, shared their expertise, and in every way have functioned as exemplary counselors for this project. Members of the Advisory Committee include the following:

- Roger Bowers, Reader in Medieval and Renaissance Music (emeritus), Cambridge University
- Roze Hentschel, Professor of English, Colorado State University
- Gordon Higgott, Historian, English Heritage
- Arnold Hunt, Curator of Historical Manuscripts, British Library, London
- Malcolm Longair, Professor of Physics (emeritus), Cambridge University
- Mary Anne Lund, Associate Professor of English, University of Leicester
- Willard McCarty, Professor Emeritus, Department of Digital Humanities, King’s College London
- Diarmaid MacCulloch, Professor of the History of the Church, Oxford University
- Damian Murphy, Lecturer in Acoustics, York University
- John Schofield, Archaeologist, St. Paul’s Cathedral
- Jeanne Shami, Professor of English (emeritus), University of Regina, Saskatchewan, Canada
- Emanuela Vai, Worcester College, Faculties of History and Music, University of Oxford

Timeline

We received our Digital Humanities Implementation Grant from the NEH in the summer of 2015, with a projected timeline of three years. The challenges of using so many part-time student workers, of organizing events in two countries, and, quite simply, of completing all the many pieces of an extremely large and complex project, made it very clear before long that a target completion date of 2018 was unrealistic. Happily, the NEH twice gave us extensions of one year, first to the summer of 2019 and then to the summer of 2020. We were then granted a blanket extension of a final year, until the summer of 2021, by the advent of the coronavirus pandemic.

The Visual Model

The development of the Visual Model started immediately, in the fall of 2015. We began with the lessons we had learned and the images we had developed while working on the Visual
Model for Paul’s Cross. Still, the development of the Exterior Model took us into 2018; the development of the Interior Model took longer, until 2020, in part because the Interior model contained elements that were challenging to model as well as parts developed in England, then incorporated into the larger model in North Carolina. The process of using the Models for renderings, for a fly-around video, and for a VR installation fully took the final 2 years of our funding period. In fact, the final renderings were not delivered until, literally, the very last day of June 2021 in which we could spend Project funds.

\[ St Paul’s Cathedral. John of Gaunt’s Tomb. \] From the Visual Model, modeled by Juan Jose Fuldain

The Acoustic Model

On the Audio side of things, the process of developing scripts, organizing recording sessions, and making the sound files took us until the spring of 2017. Editing those files took until early in 2020; auralizing took until late spring of 2021.

The Website

We view our website as the official publication of the Project. As of this writing, September 3rd, 2021, the website is complete – there is coherent material on every page of the site – but not finished. There is still much to do, in terms of revisions, clarifications, visual editing, adding documentation, references, and the like. The design, layout, and execution of the website is also under the management of Trevor Healy, yet another graduate student in architecture at NC State University, who will return to it once all the content development is done to make it as useful as we can get it.
We are also preparing to complete the Data Management Plan, in collaboration with the Special Collections Department of the NC State Libraries, as outlined in our original grant proposal to the NEH in 2015.

Challenges

Challenges have fallen into two categories. The first category is the category organizing and maintaining the day-to-day process of moving the Project forward. The other challenge is in the category of coping with the things that we could have done had we known at the beginning what we now know at the end.

Process Challenges

Given the scale of this Project, the number of people involved (often people in both England and the USA working on the same part of the Project at the same time), and the diversity of kinds of material that needed to be brought together, the major challenges had to do with coordinating people’s efforts, keeping up with individuals’ progress, and maintaining a clear understanding of where we were, how the time we had available was progressing, and how the pieces would come together once they were all done.

The major components of the Project – the Visual Model, the Acoustic Model, and the Website – proceeded along independent tracks until the very end, when each reached an appropriate level of maturity and were ready to be brought together. This has meant that much of what I have had to say about the Project at Conferences and in print has been based on promises, hopes, and expectations rather than on substantive results. Now that everything has been brought together, I personally face the challenge of getting the word out about what we have done and where our work is available.
One major challenge we faced was making progress on the Acoustic side of the Project. This involved working on both sides of the Atlantic on organizing the recording sessions, which included scheduling the use of studios, then coordinating the recording sessions with the availability of the performers, then working through the editing of the files and the use of our acoustic modeling software. The pieces of this process have come into being slowly, then came together in a rush in the first 3 months of 2021.

Another challenge came from working with so many students on the Visual Model. The students we hired were extremely talented and skilled, but they also had different levels of commitment to the Project and, often, many competing demands on their time. So, the development of the Visual Model, from the early stages of creating the wireframe structures, then providing them with colors and surfaces (what Design students call “textures”), then rendering them to include signs of aging, weather, and human presence, came in fits and starts. One group of students would learn their task, develop skills, and begin to produce work, only to finish their degrees and move on. So a new group needed to be identified and brought up to speed on the Project before productive work could begin again.

A third challenge came from the fact that so much of the work on the Project took place both in the USA and in England, which meant that I had to trust in my ability to communicate via email with a large number of people to keep the complex process moving along. I was able to attend most of the recording sessions in person, but not all. I was able to meet some of the folks working on the Project in England, but not all. Sometimes, the folks working in England were more communicative and responsive to my inquiries that were folks working on the Project in the USA. From time to time, there were breakdowns in communication between me and folks, both locally and in England. In retrospect, I should have, at least once, simply gotten on the nonstop flight from Raleigh to Heathrow and worked things out in person.

A fourth challenge came from the fact that the development of new knowledge and the discovery of new information continued throughout our process and needed to be
taken into account. Chief among them was our discovery that the style of depicting early modern buildings that we had used for the Paul’s Cross Project – with exposed structural timbers painted or stained in dark tones against the white painted plaster facades connecting them – was no longer considered accurate by architectural historians. Instead, they believed that commercial and residential buildings of this era were plastered over both the structural timbers and the connecting walls. So, while we recognized that we did not have the resources to redo the Paul’s Cross images, we did decide to show these structures in the Cathedral Project’s models according to this new evaluation of how they must have looked.

![St Paul’s Cathedral, the Paul’s Cross Preaching Station.](image)

*St Paul’s Cathedral, the Paul’s Cross Preaching Station.* From the Paul’s Cross Visual model, rendered by Jordan Gray.

What proved the convincing argument on this subject was our recognition that we were unable to find very many early modern images of domestic or commercial buildings that showed any
sign at all of the timbers that lay beneath their plaster facades. We concluded that the distinctive look of surviving examples of these buildings is, in fact, a modern creation, a reminder that, as is so often the case, concepts like “Elizabethan” or “Jacobean or “Renaissance” are in fact themselves modern creations, even fantasies of the past, not representations of lost realities.

A fifth challenge came from our recognition that records exist in the London Metropolitan Archive that show surveys of the foundations and other descriptive data about the commercial and residential structures on the south side of the Cathedral. We had known about this kind of information for the structures on the north side, and had made use of it in both the Paul’s Cross and Cathedral Projects, but this was new information. Faced with the opportunity to convert lots of structures from what we have called “representative models” to models based on hard data but the challenge that time and funds were by then beginning to run out, we decided to use this material only for our model of a central building -- the Deanery, where John Donne lived during his time as Dean – and leave wider use of this material to the future, perhaps even future generations, rather than risk not being able to complete the Exterior Model, at least in some fashion.

And, in spite of all the challenges, we did survive. We ran out of money from the NEH grant around June 1st, 2021, but were able to get a small internal grant from the English Department to tide us over. We received the very last renderings on the very last day – June 11th, 2021 – that our ability to spend institutional funds in the fiscal year 2020-2021 ran out. We got enough done to meet all our goals. The proof is all in the website.
Conceptual Challenges

In the end, the biggest challenge for me as the overall coordinator for the Project as a whole is in the recognition that the Project, as it is, achieves 99% of what we set out to achieve, but not quite all it could have achieved. Also, there are a few places in the Project where a bit more time and money at the end – when we were able to see the whole Project come together – could have made a small, though significant, difference in the overall quality of what we did.

*St Paul’s Cathedral, the Choir from Above.* From the Virtual Reality Model, created and rendered by Grey Isley.

The chief disappointment is that the Virtual Reality Version falls short of our ambitions in several ways. We originally hoped to have the VR version include a self-guided tour of the External Model, as well as of the entire Internal Model. We hoped that the VR Version would incorporate the Paul’s Cross Project as well as the Cathedral Project. We gradually cut back on our goals as time drew short, to include only the Cathedral’s Choir, where the worship services at the heart of the Project were conducted. Then we hoped that the Choir Only Version would include all the recorded worship service material, so it would have provided a fully multi-media experience rather than a visual-only experience.

*St Paul’s Cathedral, the Choir from Above.* From the Virtual Reality Model, created and rendered by Grey Isley.
However, Grey Isley, the person developing the VR Version discovered, in the late spring of 2021, that while the Visual Version worked fine, he was unable to link the audio material to the visual presentation. If we had had time and funds to support Grey in sorting this out, we could have had that fully multi-media version. But we didn’t. So we have what we have, an experience still far beyond the dreams of the original plan.

Other disappointments concern instances in which problems with the material included on the website could have been fixed if I had recognized them sooner or had the time and funds to fix them once they were recognized. Here is a preliminary and, I am sure, incomplete, list:

A. We could have achieved a greater consistency in visual depiction. Some of the renderings show earlier versions of the Visual Model with details that were revised in later versions. These include things like the style of depicting doorways, the angle of the paving stones on the Cathedral’s floor, the existence and location of grave markers, again in the Cathedral’s floor.

B. We could have had greater accuracy in the depiction of buildings in Churchyard. We learned about 2/3rds of the way into the Project that descriptions of a number of buildings in the Churchyard were contained in the records of the Cathedral’s Dean and Chapter, now in the possession of the London Metropolitan Archive. We were able to use this material in the model of the Deanery we made for the Churchyard but not for the other buildings for which we know there is more information than we started with.

C. We could have had a greater accuracy in depicting the dress of the figures we include from time to time in the Visual Model. There are figures in the Visual Model who are wearing the clothing of townspeople when they ought to be wearing clerical vestments.

D. We could have had a greater accuracy of sound reproduction. In the music selections on the website, sometimes the organ is too loud and obscures the voices of the singers. We found out later that the auralizing software had a built-in equalizing feature that boosted the organ tracks. With a bit more time and money, we could have fixed this.

St Paul’s Cathedral, the South Transept, with the Treasury. From the Visual Model, rendered by Austn Corriher.
I have thought on numerous occasions that what we really needed for this Project was the special effects budget of a major motion picture. But we didn’t. Oh well.

4. Project Outcomes

The most significant outcome of the Virtual St Paul’s Cathedral Project is the Project’s website, https://vpcathedral.chass.ncsu.edu/.

- The website provides access to the Visual Model through a fly-around video, through guided tours of both the Exterior and Interior Models, through panoramic views of the Interior Model, through rendered images of a variety of views of both the Exterior and interior Models, and through a Virtual Reality experience of the Choir.
- The website provides access to the Acoustic Model through auralized recordings of four worship services on Easter Sunday 1624, a festival day, and two worship services on the Tuesday after the First Sunday in Advent 1625, a ferial, or ordinary day, for a total of nearly 8 hours of recordings.
- The website integrates the Visual and Acoustic Models by enabling the user to experience all the worship services from five different listening positions within the Cathedral’s Choir.
- The website also gives access to a Virtual Reality installation of the Cathedral’s Choir, playable either on one’s computer or with an Oculus or Vive headset, and its uploading to the website.

*St Paul’s Cathedral, the Altar Area.* From the Visual Model, rendered by Austin Corriher.
• The website also includes extended discussions of how we made all the models, together with a collection of all the historic images we used to make the models and a discussion of the opportunities and limits of digital modeling based on use of historic data.
• The website also includes extensive background information on the Church of England, on John Donne’s career, and on St Paul’s Cathedral, post-Reformation, to provide a historic context for the events we recreate through the models.
• The website also includes discussion of how worship services were organized according to the Book of Common Prayer, so people who wish to recreate worship services on occasions other than the ones we model will be able to do so.
• The website also includes guidance to further research into Donne’s career, into the conduct of worship in cathedrals and collegiate and parish churches, and into the character of the post-Reformation Church of England.

Audiences

The primary audience for this Project is the scholarly audience for studies in early modern history, literature, architecture, archaeology, religion, and culture. There is also the extended audience consisting of visitors to the Project’s website. I have not started keeping track of the visitors to the Cathedral Project’s website yet because it is not completely finished, but visitors to the Paul’s Cross website over the past seven years exceed 100,000.

The chief secondary audience is a more general audience involving informed clergy and lay folk interested in the history of the Church of England and of the Episcopal Church in the USA. Another secondary audience is people for whom the idea of seeing spaces and buildings destroyed by the Great Fire in 1666 and hearing worship services as though they were being conducted in these lost spaces has a charm and a fascination.

*St Paul’s Cathedral, the Altar Area.* From the Visual Model, rendered by Austin Corriher.
Technical Decisions

We used standard software for visual modeling, including SketchUp, Lumeon, and Photoshop. We developed i-Pack Simpa, our own acoustic modeling software, as described elsewhere in this report, and used CATT-Acoustic, a commercial acoustic modeling software as a basis of comparison for the capabilities of our product. We also use Audacity, an acoustic editing software for editing of sound files.

Challenges relating to documentation

We have had to pay for website use of a number of the visual images depicting historic views of buildings.

St Paul’s Cathedral, the Nave, looking East. From the Visual Model, rendered by Austin Corriher.

Personal and Professional Outcomes

We have reason to believe that participation in this Project was significant for the careers of its participants. When we started the Paul’s Cross Project, David Hill was an untenured Assistant Professor in Architecture in NC State’s College of Design. He now has been promoted to the rank of Full Professor and serves as Head of the Architecture program. Yun Jing was an Assistant Professor teaching microwave behavior, even though his PhD was in acoustic engineering. He has now been promoted to the rank of Associate Professor with tenure and has moved on from NC State University to Penn State University, where he has joined a strong program in acoustic engineering. I was awarded recognition by my College as Research Faculty Member of the Year in 2018.
More important, perhaps, our grants from the NEH have helped fund members of ten classes of students in the Masters in Architecture program at NC State. They have also helped fund the academic careers of several students in the College of Engineering.

Sources of Information

The primary source of information will continue to be the Project’s website. In addition, the NC State Office of Communications is preparing a story on the Project to be released within the month. We had plans for public lectures in London to take place – one at King’s College London and the other at Wren’s St Paul’s Cathedral – in the fall of 2020, but they had to be postponed because of the pandemic. I will continue to publish articles in scholarly journals and give talks at professional meetings, as the occasion permits.

*St Paul’s Cathedral, the South Front.* From the Visual Model, rendered by Austin Corriher.

5. Project Evaluation and Impact

Our chief sources for assessing the impact of this Project on the primary audience so far are invitations to speak at scholarly conferences and acceptances of essays on the Project in scholarly journals and monographs. To date, I have presented fourteen papers on the Project at scholarly conferences, including an invited one-hour lecture at the Annual Conference of the John Donne Society at LSU in 2020. I have to date published eight scholarly articles on the Project, with one more accepted for publication and making its way through the publication process.

Published essays include the following:


In addition, the Paul’s Cross Project was named the Best Data Visualization Project (DH Awards Program), for 2014 and received the John Donne Society’s Award for Distinguished Publication, for the Virtual Paul’s Cross Project website in 2013.

St Paul’s Cathedral, the Choir Screen. From the Visual Model, rendered by Austin Corriher.

There have also been two major reviews of this work, both dealing directly with the Virtual Paul’s Cross Project. Both were positive. One was in Spenser Review.
I learned, as we worked through the data, and worked the data up into models, and spent time with the interaction of the models, was the value and significance of our original premise – that the structuring of the daily and weekly worship life of the Church of England was the most important thing about the Church of England post-Reformation. The documents – the Book of Common Prayer, the Great Bible, the Books of Homilies and their ancillary documents – that made daily and weekly worship possible were as central to the post-Reformation Church of England as the theological writings of Luther, Zwingli, and Calvin were to their traditions. Through this structure of public worship, Cranmer and his followers sought participation in the Christian life through corporate reading of the Bible, prayers to God, intending to lead a new life, and finding in unity with Christ at Communion their identity with Christ’s “mystical Body.”

I now know more fully how this pragmatic, corporate, liturgical, and sacramental tradition did its work, so that, in the words of Eamon Duffey, “Cranmer’s “somberly magnificent prose” entered and possessed “their minds, and became the fabric of their prayer, the utterance of their most solemn and their most vulnerable moments.”
I have also learned how much the results of historic research is shaped by the assumptions with which a scholar approaches the topic and the cognitive framework used by the scholar to understand the subject. The perspective one takes, and the tools one brings to the task have a lot to do with shaping the result of one’s study.

The data for understanding the post-Reformation Church of England is immense and fragmentary. All of the players in this saga use a common set of resources for making meaning of this data. They share the texts of the Bible, the writings of Christian tradition, the historic creeds, the experiences of worship and study. They speak the same language but use different dictionaries.

Scholars who approach this material need to ask themselves what backgrounds they come out of and what dictionaries they, too, bring to this material. Scholarly work is often autobiographical. The more we are aware of where we are from and what assumptions we bring with us, the more likely we are to attend to the material before us in its terms rather than in our own.

![St Paul's Cathedral, the Altar from Above. From the Visual Model, rendered by Austin Corriher.](image)

What I Learned as a Grant Applicant

I learned that the NEH gets vastly more grant applications than they can possibly fund. So the work of the applicant is to find ways of distinguishing one’s application from others. One way of doing this is to avoid asking for funds to do the kind of project that other people are already doing. The goal therefore is to propose doing something that others are not. When we started applying for funds for this Project, people had already begun to generate a variety of kinds of visual models. What made our first grant successful was its combination of visual and acoustic modeling.
Another way of doing this is to propose the development of a research tool that could be used more generally by scholars as the goal of one’s project, or as part of the process for completing a related project. What made our second proposal fundable was our commitment to creating an open-source acoustic modeling package; our original goal of recreating worship inside St Paul’s Cathedral now became the opportunity to demonstrate the usefulness of our research tool.

Another way of doing this is to ask for a small amount of funding to achieve a specific goal which, if successful, would demonstrate the value of additional funding to achieve a larger, though related, goal. So, our proof of concept project was Virtual Paul’s Cross, which not only demonstrated the value of combining visual and acoustic modeling but also became an essential part of, and a complement to, the Virtual Cathedral Project.

Finally, my advice is that – from the very earliest stage of developing one’s proposal – one makes appointments with and takes the advice of the appropriate Program Officers at the NEH. They know the kinds of projects that will get strong positive responses from the review committees. They know what a strong proposal looks like. They are on your side. Get to know them.

6. Project Continuation and Long-Term Impact

Short-Term Goals

My short-term goal is to complete work on the website. I will implement the Data Management Plan previously agreed to with our University Libraries. I will also continue talks with the Libraries
about use of material from this Project to demonstrate the capabilities of their new digital research facilities in our D H Hill Library.

I also plan to continue announcing the availability and achievements of the Project. I have, for example, accepted an invitation to present a report on the Project at the 2022 meeting of the Renaissance Society of America and will seek other such opportunities from appropriate professional organizations, such as the John Donne Society, the Southeastern Renaissance Conference, and the Historical Soundscapes Conference.

I will also seek to deliver talks in London originally scheduled for the fall of 2020 but deferred by the onset of the current pandemic. I will also seek recognition from awards programs like the Digital Awards Program that recognized the Virtual Paul’s Cross Project in 2014.

Further Research

As far as further research is concerned, I have included on the Project website a series of proposals for further research into the life and career of John Donne, the post-Reformation Church of England, and the relationships between worship in English cathedrals and worship in parish churches. I may do some of that myself. I do plan to write more about John Donne and the daily worship of the Cathedral, focusing on his frequent references to that worship in his *Devotions Upon Emergent Occasions*. I also plan to complete development of the remaining websites that are also part of the Virtual Donne Collection, here <https://virtualdonne.chass.ncsu.edu/> . These include the Paul’s Cross site, the Cathedral site, and the Trinity Chapel site, which reconstructs Trinity Chapel at London’s Lincoln’s Inn as it was when it was consecrated on May 22nd, 1623. Donne, who had been Chaplain for Lincoln’s Inn before becoming Dean of St Paul’s Cathedral in 1621, preached at that ceremony.
I also hope to contribute to a conversation about the role of University Libraries in dealing with digital humanities projects. My university’s Libraries have agreed to archive files that were generated in the course of the Virtual St Paul’s Cathedral Project. But they have not agreed to host and maintain the website itself.

This seems to me to be an abandonment of one of the most fundamental responsibilities of a university library – to acquire knowledge, to conserve it, and to make it available to students and scholars. To speak personally, I have devoted the last third of my career to working on this Project. We have received two major grants from the NEH to fund this work. As a result we have spent nearly $400,000 of taxpayer’s money. At the moment, the website lives on university server space, available to all. But the cost of maintaining the website on that server space is borne by my department, as an annual fee.

My current Department Head supports this Project and promises me that it will continue to be available until she retires as Head. That is OK, except she plans to remain as Head only for the next couple of years or so. After that, the decision about whether to continue funding bill for rent on the server space will be in the hands of her successor as Head. But that person may have other priorities. So, without the Libraries’ support, it is entirely possible that access to our website, and to all the work we have done, and the NEH has invested in so significantly, may vanish in two years.

*St Paul’s Cathedral, the Great Rose Window.* From the Visual Model, created by Caroline Cox.

**Acknowledgement of Gratitude**

A Project of this scale and duration would not have been possible without the support and collaboration of lots of exceptionally talented and able people. I have had the good fortune to meet the right people at the very time I needed to meet them.
I, personally, am deeply grateful to David Hill and Yun Jing, who have been the best colleagues imaginable. They saw from the beginning how their expertise could make the Project happen, and it did. Their exceptionally talented students produced models and rendered images, and created the website. They created i-Pack Simpa and auralized our sound files. Without them, none of this would have happened.

The distinguished scholars John Schofield, Roger Bowers, and David Crystal took a chance on the vision of a total stranger. Richard Pinel, Choirmaster of Jesus College, said that his Choir could play the role of the Choir of St Paul’s in the 1620’s. And they did. Without them, none of this would have happened.

The recording engineer Matthew Dilley, of About Sound in Cambridge, England, said he could make “dry” recordings of groups of performers without using an anechoic chamber, and he did. Without him, none of this would have happened.

Neal Hutcheson said that he could edit the sound files so that Seth could auralize them, and he did. Without him, none of this would have happened.

The acoustic engineers Ben Markham and Matt Azevedo said that they could create the sounds of Paul’s Churchyard, and they did. Then, they took on Seth Hollandsworth, an undergraduate Engineering major at NC State as a summer intern, and taught him how to create the sounds of worship in the Choir, and he did. Without them, none of this would have happened.

Grey Isley, while a graduate student in Design at NC State, created much of the original Cathedral model. Then, when he returned as a PhD student, he said he could create a Virtual Reality version of the model, and he did. Without him, none of that would have happened.

My Department Heads Laura Severin and Antony Harrison, provided their support throughout the planning, development, and realization stages of this Project. Without them, none of this would have happened.

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Special Thanks

Special thanks also go to the distinguished digital humanist Bernard Frischer, a pioneer in visual modeling. When Dr Frischer was Head of the Institute for Advanced Technology in the Humanities (IATH) at the University of Virginia in the early 2000’s, he met with me, even though at that time I had had several applications for funding to support the digital recreation of St Paul’s Cathedral and its Churchyard rejected by the National Endowment for the Humanities.

Dr Frischer was generous with his time and knowledge. We discussed at length the processes through which he had developed the pioneering digital model Rome Reborn and how they might apply to the modeling of St Paul’s Cathedral. He reviewed the resources I had identified for developing the Visual Model. “Yes,” he said, you can create this model, and here’s how.”

And then he said, “And you can hear it too.” And that has truly made all the difference.

*St Paul’s Cathedral, the Ceiling.* From the Visual Model, rendered by Austin Corriher.