# Plumage
## A Stereoscopic 3D Experience

Gwendolyn V. Sewell

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Thomas J. Tucker, Chair
Dane L. Webster
Jennifer L. Hand

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## ABSTRACT

*Plumage* is a stereoscopic 3D experience showcasing the culmination of a personal exploration and observation of birds: a digitally modeled and rendered, fantastical bird referred to simply as a Phoenix. In many cultures birds are tied to ideas of freedom, power, and the otherworldly. Preconceived notions of a phoenix exist across many cultures as well, but for this project I wanted to create my own interpretation.

While working, I drew upon my admiration of birds for their qualities of strength, beauty, and curiosity to infuse into the project. Inspired by the dynamic and detailed works of naturalists like John James Audubon, I took the opportunity to make my own observations and records of birds.

I began exploring different processes of digitizing three-dimensional forms by scanning bird skins. However, due to the nature of fibrous and reflective materials (of which birds are often both) I ran into challenges that made accurate and detailed representation difficult if not impossible. From there I made the decision to pursue a more imaginative artistic approach to the project.

More than just a homage to feathers and birds, this project represents the continued value of artists in the field of preservation and their ability to push visuals further with their own observations where automation and digitization fall short. Using life references I created my own textures and forms with details meant to emulate my favorite aspects of the birds that inspired me throughout my journey.

Larger-than-life, projected stereoscopic 3D allows the audience to see details clearly and enhances the dynamic quality of the piece; both very important elements that needed to shine through in the final artwork. *Plumage* is made possible through the use of the Cyclorama, a series of convex screens that surround an audience and allow them to appreciate scenes projected in stereoscopic 3D.

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## GENERAL AUDIENCE ABSTRACT

*Plumage* is a projected 3D experience that uses state-of-the-art projectors, 3D glasses, and a large, cylindrical screen--known as the Cyclorama.

My research began with a focus on 3D scanning dead bird specimens from a museum collection as a means to archive them and make them viewable by anyone with access to a computer. Unfortunately, the scanner I used could not effectively capture the intricate shapes and colors of feathers, and the resulting scans were not sufficiently detailed for learning or archival purposes.

In the end, I used the observational data I had collected from the bird specimens to digitally sculpt my own ficticious species of bird. I closely studied the feathers and wing structures of the birds available to me to recreate a detailed, digital 3D representation where scanning had failed.

Using software, I created still images of the finished digital bird sculpture. To create the 3D effect when projected onto a screen, I created pairs of images for the left and right eyes. The projectors and 3D glasses, coordinated with a powerful computer, allowed the audience to experience convincing 3D effects such as the Phoenix jumping out or sweeping a wing at its audience.

# Acknowledgements

I want to express my thanks to committee chair Professor Thomas Tucker for his time, patience, and support throughout this project and its many challenges and changes. I also want to thank Professors Dane Webster, Jennifer Hand, and Carol Burch-Brown for their guidance and encouragement throughout the years. Their contributions to their students will be fondly remembered and appreciated.

Special thanks to Xindi Liu for his time and effort spent helping me in the DAAS Lab and Cube. His knowledge, persistence, and cheer were all invaluable in the completion of this project.

# Table of Contents

# List of Figures

# Introduction

Early in my childhood my parents gave me a book of prints by John James Audubon, whose depictions of birds sent my imagination running wild. Many of them were very unusual-looking, and even past my childhood I can say that Audubon depicts many of his birds in a dramatic way that makes them seem larger-than-life. His textures and linework give his creatures a quality that almost makes them seem tangible, and to me they have always seemed expressive in a wild kind of way.

Audubon's work always stood out to me because I had access to such a broad collection of his prints as a child, and many of them were of native species that I saw every day. Every time I looked through the book I noticed new details, or found new stories being told for each bird species. Seeing his work encouraged me to go out into the world and experience some of those details and stories for myself.

**Figure 1.1**: Plate 226 "Hooping Crane" John J. Audubon (http://www.audubon.org/birds-of-america/hooping-crane-0)

I believe that some of these early influences are what drove me to become an artist, and why my work tends to focus so heavily on observation and detail. Needless to say, Audubon's work has been an amazing inspiration for the duration of this project.

**Figure 1.2**: Plate 102 "Blue Jay" John J. Audubon
(http://www.audubon.org/birds-of-america/blue-jay)

**Figure 1.3**: Plate 211 "Great Blue Heron" John J. Audubon
(http://www.audubon.org/birds-of-america/great-blue-heron)

# Early Exploration and Research

When I first began the Creative Technologies Masters program at Virginia Tech, I knew that I wanted my work to involve an exploration of creatures or nature, real or imagined. At the time I was learning how to make optimized 3D objects and characters for game engines. One of the first birds I attempted to model was based on my own concept for a character to be used in a videogame.

**Figure 2.1**: Roadrunner concept

I referenced a number of birds both in real life and in games to create the character concept. The end result was very simplistic in order to run in a game engine, and also because I lacked a general understanding of bird anatomy. Feathers provided a unique set of challenges. There can be hundreds of thousands of feathers on a given bird, but most game engines cannot run models with too many polygons or details. Feathers must be created extremely efficiently, and the resolution of textures is usually fairly low to optimize the character even further. Creating content for real time engines has a lot of constraints that need to be addressed before designs are finalized.

**Figure 2.2**: Roadrunner final model

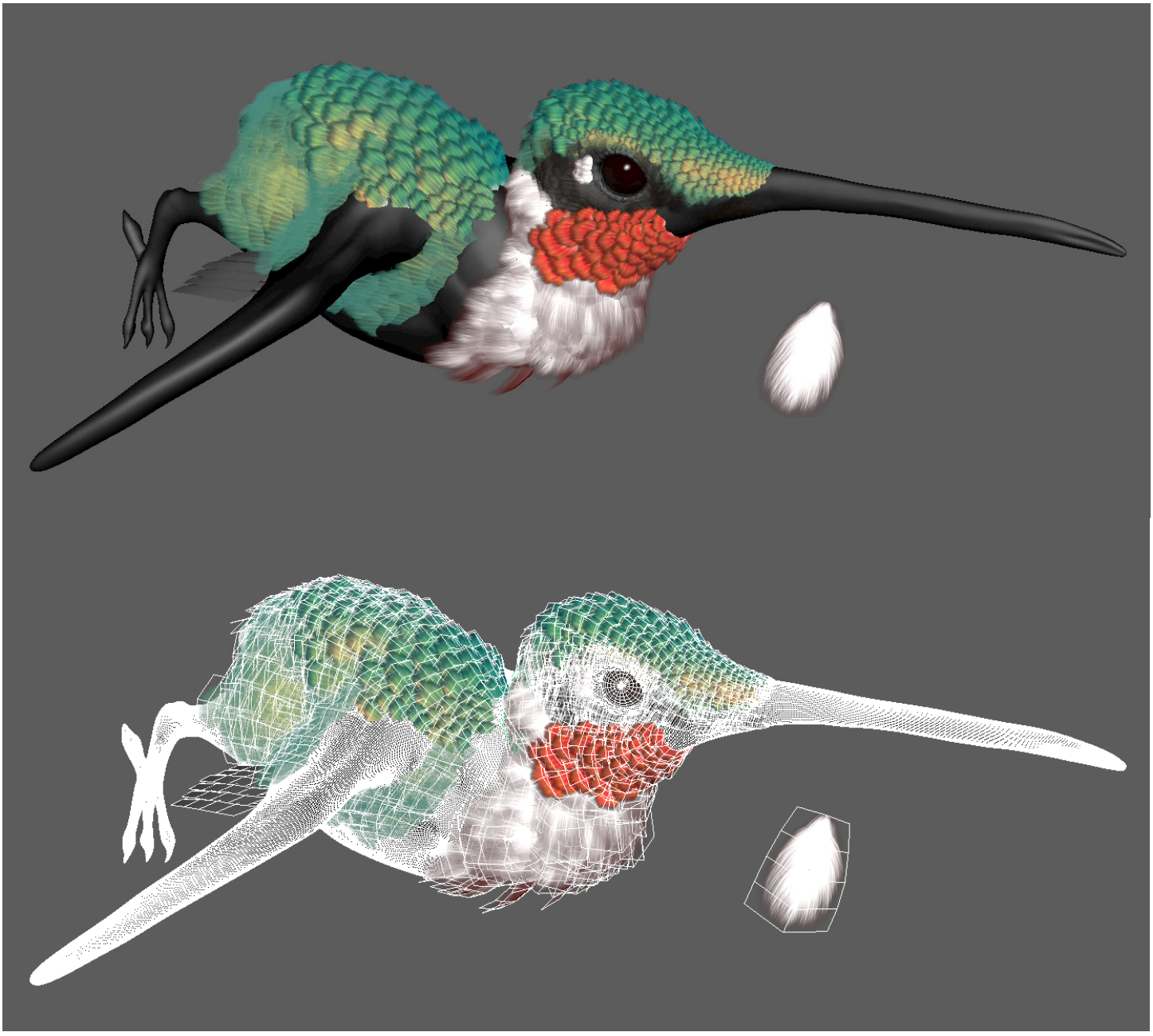

**Figure 2.3**: Ruby-throated hummingbird study. Model showing an example feather with transparent textures, and the underlying polygons

I wanted to explore creating birds with more detail, and eventually the game engine idea was abandoned in favor of pre-rendered visuals that are able to make use of more complex, higher-resolution models.

I began exploring different ways of modeling birds and feathers. The most effective way of creating the feathers themselves was to create a polygonal plane with a transparent texture that simulates the wispy edges feathers have.


**Figure 2.4**: An exhibit of extinct passenger pigeons. Photo taken at the Smithsonian Museum of Natural History

For references I used public digital libraries of animal scans. On one occasion I visited the Smithsonian Museum of Natural History during its exhibit, *Once There Were Billions* to photograph the variety of living and extinct birds in its collection.

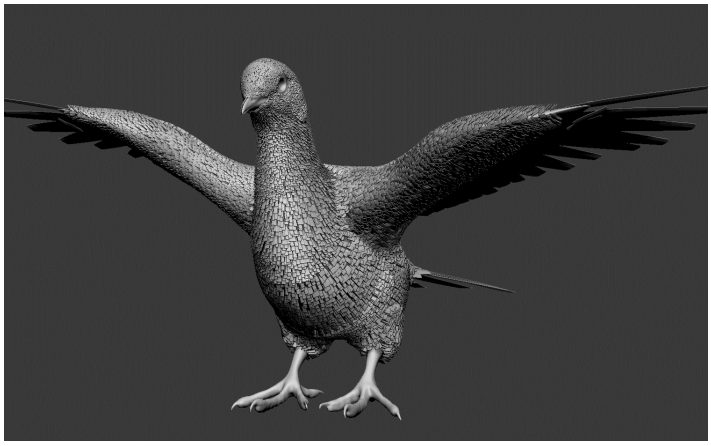

**Figure 2.5**: Early exploration of a passenger pigeon. Feathers created through FiberMesh, a tool in Zbrush

These studies were useful but I wanted a more thorough understanding of birds. To supplement my studies I took an ornithology class under Dr. Dana Hawley. The class was very important in gaining a better understanding of bird anatomy but also led me to the work of other amazing bird artists, like David Allen Sibley. His work serves as a wonderful guide for bird watchers and students, and seeing the amazing clarity he put into every feather of his subjects served to inspire me further.

# Beginning Digitization

The following summer I interned with the Smithsonian's Digitization Department. While there I focused on learning methods of digitizing objects and cleaning up the resulting data for different purposes. The Smithsonian's emphasis on digitizing objects to preserve them and share that information with the world left a lasting impression on me.

The following semester when I returned to Virginia Tech, I was eager to find a way to apply what I had learned at the Smithsonian to something I was enthusiastic about: birds.

I inquired about using the Department of Biological Science's collection of bird skins. With the help of Dr. Michael Rozensweig I was granted access to the specimens lab. I initially wanted to digitize the historical collection of birds, and much in the spirit of the Smithsonian, share it as a learning tool for students and others interested in learning about the collection.


**Figure 3.2**: Tag with information about the bird and scanning locator dots in the background

**Figure 3.1**: Drawer of cedar waxwing specimens

During my internship I learned about two methods of digitization: photogrammetry, and scanning.

Photogrammetry is a process that uses photography to digitally recreate objects from life accurately. It is used often for buildings, landscapes, and other large objects. The process involves taking photos of an object from all angles, and then stitching them

**Figure 3.3**: Passenger pigeon skin resting on turntable used for photogrammetry

together through the use of software to create a three-dimensional object. In order to accurately capture the bird skins I placed them on a turntable which allowed me to photograph the skins from a fixed point. The software I used to process the photographs was Agisoft.

**Figure 3.4**: A completed wood duck model using Agisoft software. Each blue rectangle represents a photograph taken in relation to the original taxidermied animal

Photogrammetry was an incredible tool for recording color information, however the models themselves required a lot of cleanup and individual feathers were not captured with the desired amount of detail.

The wood duck in figure 3.4 above gave fair results, however the smaller songbird specimens that made up the majority of the collection often lacked details and color information in the wing feathers and feet. Due to the lack of detail and necessary cleanup, I looked to scanning as another possible method for digitizing the skins.

3D Scanning requires specialized equipment that is capable of quickly recording surface coordinates of an object. I used a ZCorp handheld scanner to rapidly capture both the surface and color data of the skins. The required setup was a board with a grid of locator dots, which help the scanner track everything being scanned as the user moves it.

The process of digitizing the skins was much faster with the use of a handheld scanner, however much like photogrammetry, scanning had its own drawbacks. Color information was not nearly as accurate; many scanners have problems capturing color and even surface

**Figure 3.5**: Using the Zcorp handheld scanner to scan a falcon

**Figure 3.6**: Northern flicker skin resting on scanning platform with locator dots

data if the item is reflective or black. The level of detail on the feathers was much improved from photogrammetry, however definition in some regions of the bird remained poor, especially in tight places near the feet and

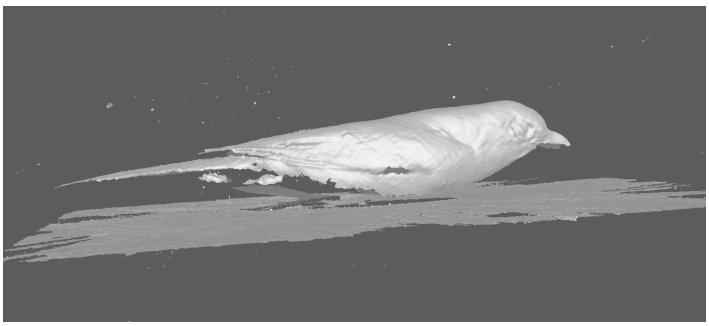

**Figure 3.7**: Scan of a northern shrike using the handheld scanner

under the wings Overall the level of detail I had expected from digitizing the skins versus the end result was considerably different. Scanning the entire collection of bird skins seemed like an unrealistic goal, so I began to reevaluate the project.

# Life as Reference and Inspiration

I made the decision to revisit sculpting birds from scratch when I realized that neither photogrammetry nor scanning were capable of capturing details to the desired degree. I decided to take the project in a more imaginative direction, using the bird skins as references and inspiration. The skin collection featured a plethora of bird species and feather types that I could not hope to see up close in any other setting.

I began working on my own species of bird based on the feathers of the birds in the collection that inspired me most. The most intriguing for me were the Greater Birds of Paradise with their fiery, explosive tail feathers. The element of fire inspired me to make the invented bird a phoenix. Seeing all the feathers encouraged me to explore the details of their color and structure and integrate them into my own bird.

**Figure 4.1**: Top to bottom: body and tail feathers from greater birds-of-paradise, and a black-throated magpie-jay

# Exploring Feathers

**Figure 5.1**: Iridescent green plumage of a resplendent quetzel

The feathers on an individual bird vary greatly in size, color, and texture. Different regions of a bird may have drastically different feathers that serve different purposes, whether they are for flying, display, or camouflage. Some feathers may be scale-like, and others more like hair. I was very driven to find out more about these structures, which led me to buy a phone-mounted microscope intended for closer inspection.

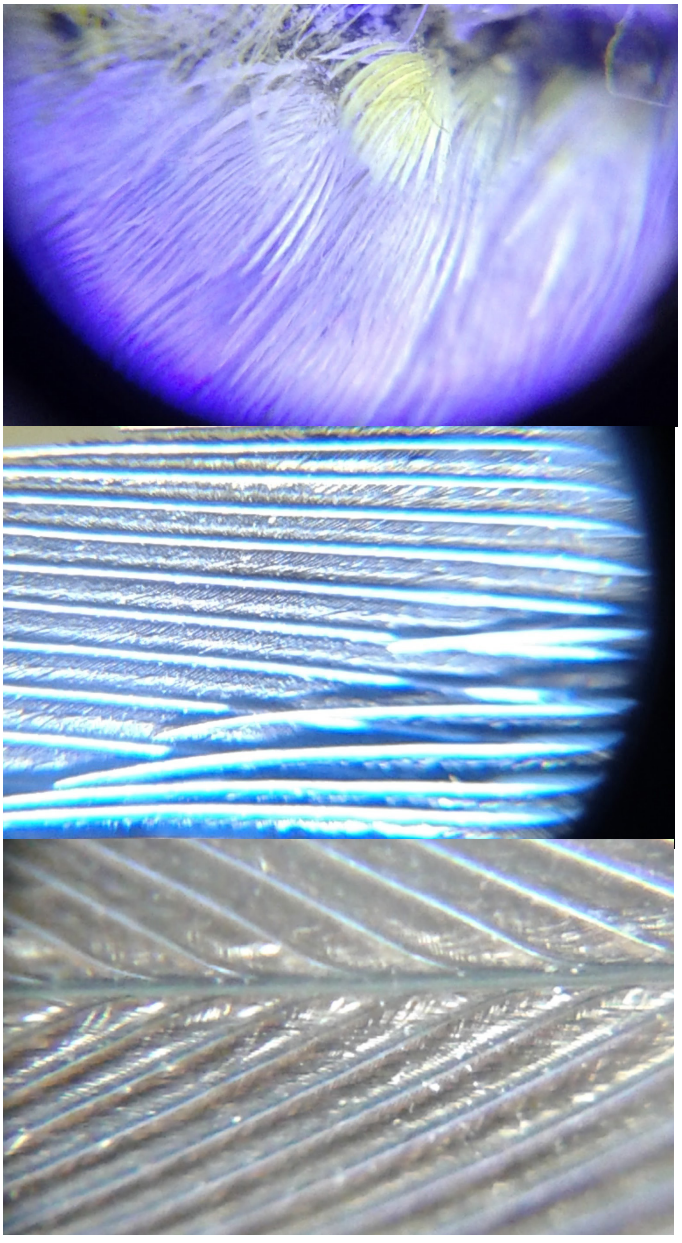

**Figure 5.3**: Magnified feathers

**Figure 5.2**: King bird-of-paradise with brilliant red plumage

# Creating Feathers

Figuring out feathers was the most challenging part of this project. From the beginning there were many issues to cover: the question of stylistic choice, learning about the feather topology of birds, how feathers interact with the bird's anatomy, how to quickly and effectively add feathers to a bird model and lastly, the structure of the different types of feathers.

Early on I experimented with different ways of feathering my birds. Eventually I settled on using Zbrush's FiberMesh tool to create fibers that cover defined surfaces of a model. My first attempts at using the tool were heavy-handed and gave poor results, but with practice I was able to create many of the feathers on the phoenix's body in different shapes and densities.

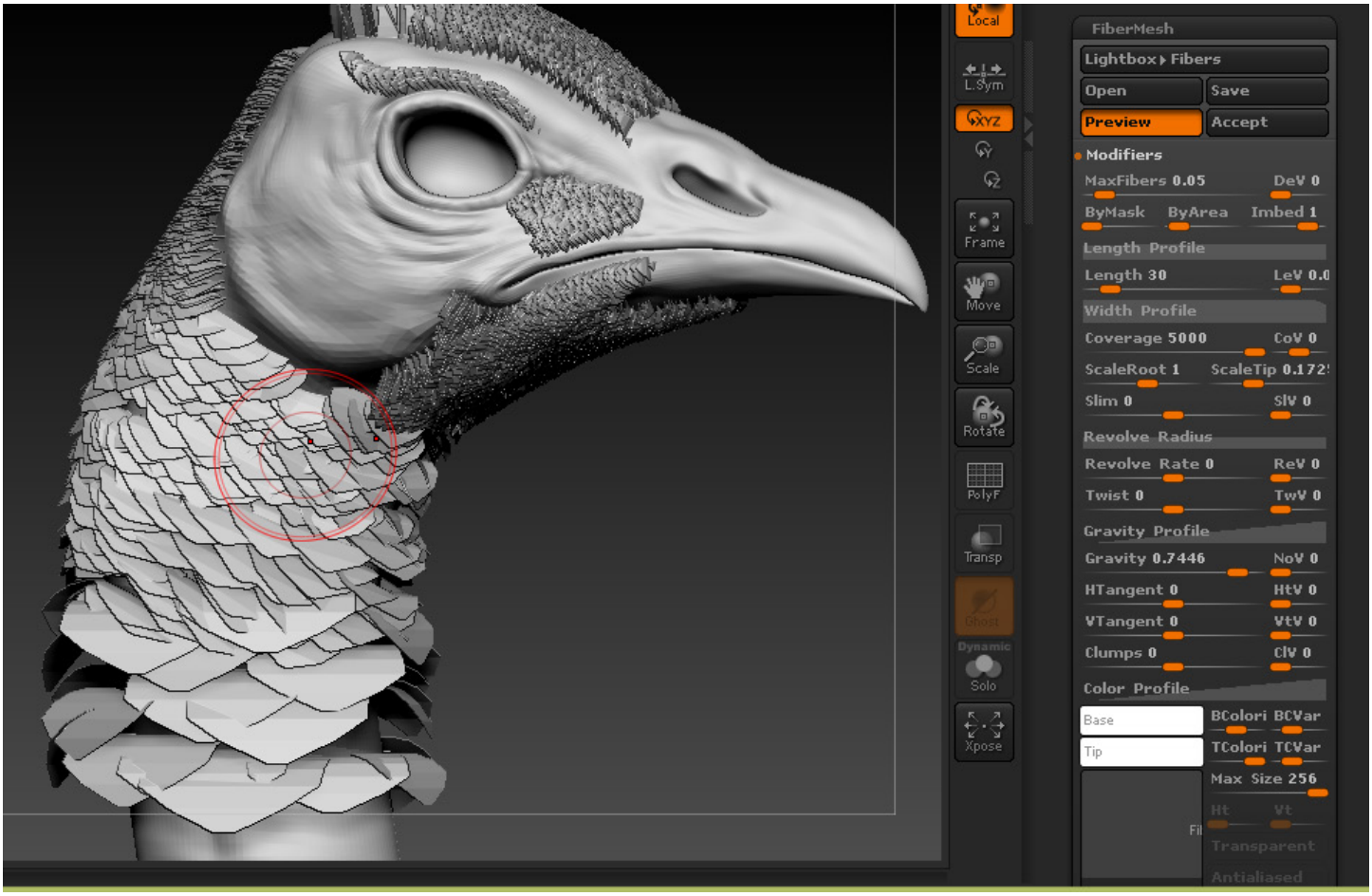


**Figure 6.1**: Using FiberMesh inside of Zbrush

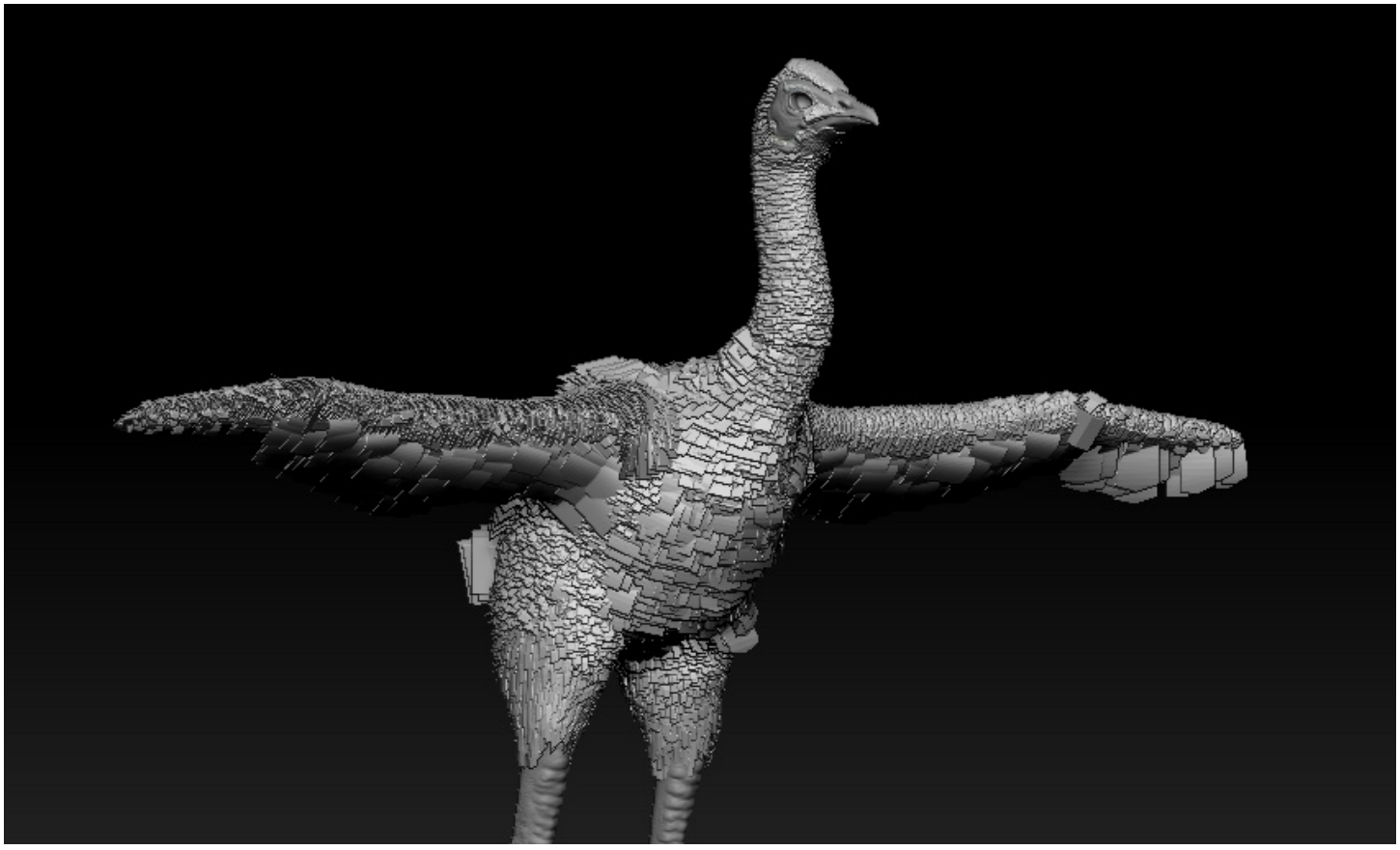

**Figure 6.2**: Completed body feathers

When I began creating my own birds there was no question for me that I wanted to create my own textures. The textures needed to have the regular patterns in structure that feathers have, allow for transparency, and be adaptable to different shapes and sizes. Based on what I knew about Photoshop and some of its brush-creation tools, that seemed like the logical solution. To create my feather brushes I used a repeating curved pattern to emulate the regularly repeating barbs that make up a feather.

**Figure 6.3**: Feather brush examples

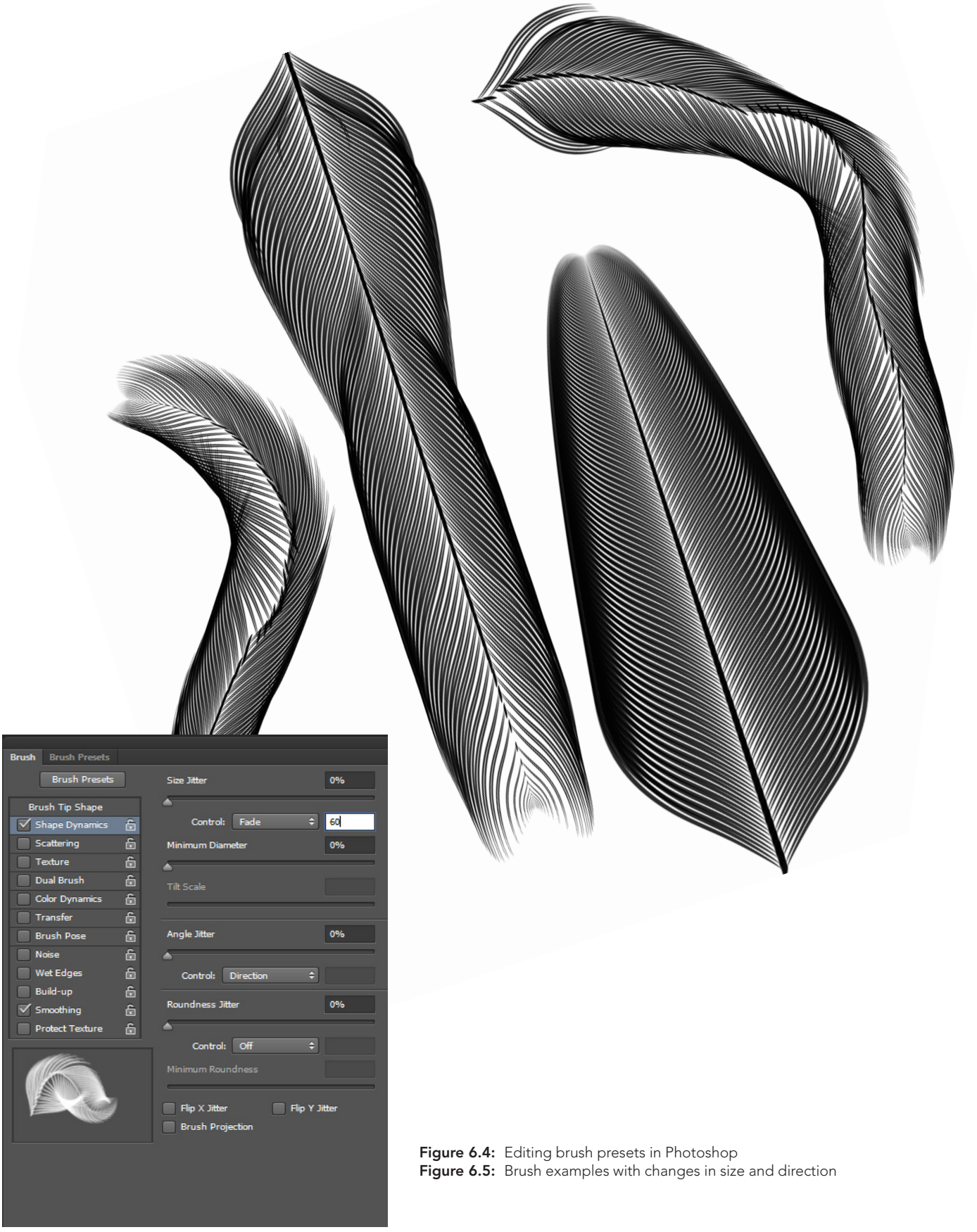


**Figure 6.4:** Editing brush presets in Photoshop
**Figure 6.5:** Brush examples with changes in size and direction

# The Bird Underneath

Much of a bird's anatomy and the way it moves are hidden underneath a layer of feathers. Understanding how birds' bodies look without their feathers was necessary for me to be able to sculpt the body, and, eventually move on to feathering it using Fibermesh. An amazing reference I managed to find was a book of scientifically accurate bird illustrations by Katrina van Grouw called *The Unfeathered Bird*. The book was extremely useful because of the variety of birds it featured--sans feathers. I referred to many of these illustrations as I sculpted the phoenix's body and surface details.

**Figure 7.1:** Phoenix, unfeathered

For the color of the bird's skin I referenced birds like peacocks and cassowaries which have unfeathered, brightly-pigmented skin around their head and face.

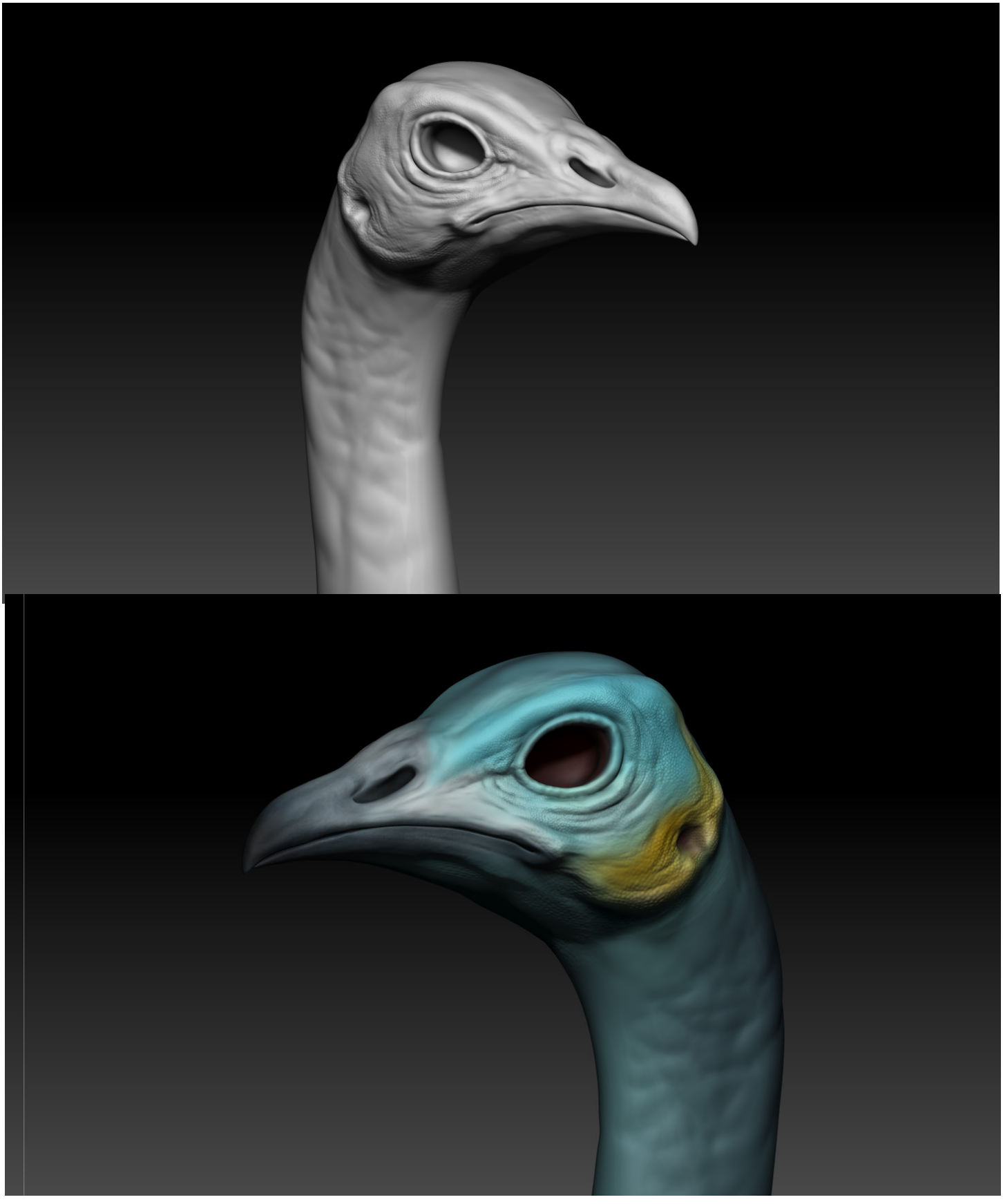

**Figure 7.2:** Phoenix head details

# The Rig

After the completion of the mesh, I wanted to build a rigging system that would give the phoenix a wide range of movement for posing and animating. I used inverse kinematics handles for the wings, neck, legs, and tail to give them a desirable range of movement. The three pieces of the elaborate tail were rigged seperately from the body in order to give them their own range of movement and maneuver them behind the wings when necessary.

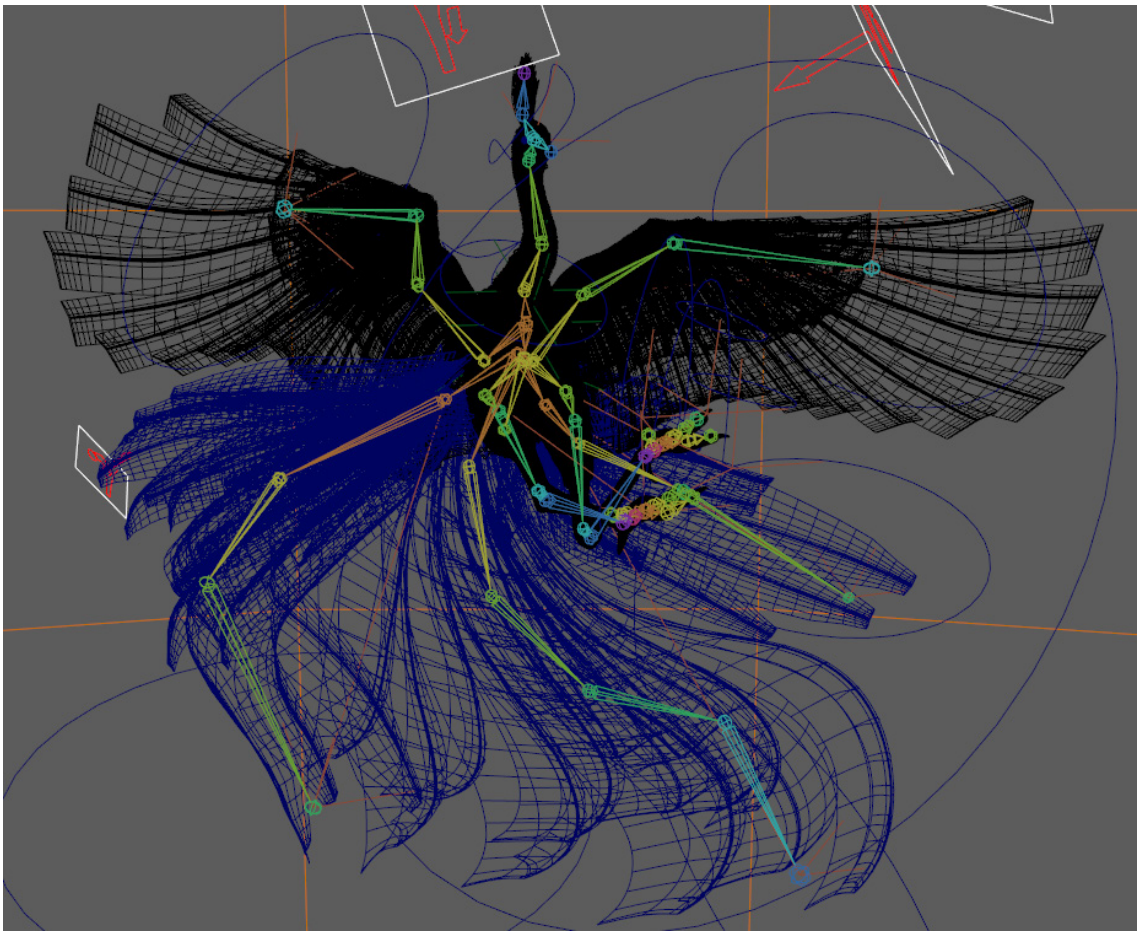

**Figure 8.1:** Posed rig showing skeleton

# Stereoscopic 3D and the Cyclorama

The effect of stereo 3D is created using two images rendered at different calculated angles that focus on the same point, simulating the depth humans see with two eyes. To create the phoenix I rendered 3000 x 1000 pixel stills and animations for both eyes, which were then combined and projected with the Cyclorama. The Cyclorama uses a system of two projectors per screen that work in tandem with glasses that rapidly swtich between the left and right eye image. This creates the impression of three-dimensionality and depth.

Using stereoscopic 3D was an engaging way of presenting the phoenix to my audience that went further than a game engine or print. It gave the bird a dramatic presence which was emphasized by the poses and placement of the zero-parallax plane, which gave the impression that the bird was sweeping a wing close to its viewers, jumping at them, or pecking at them; depending on the focal point.

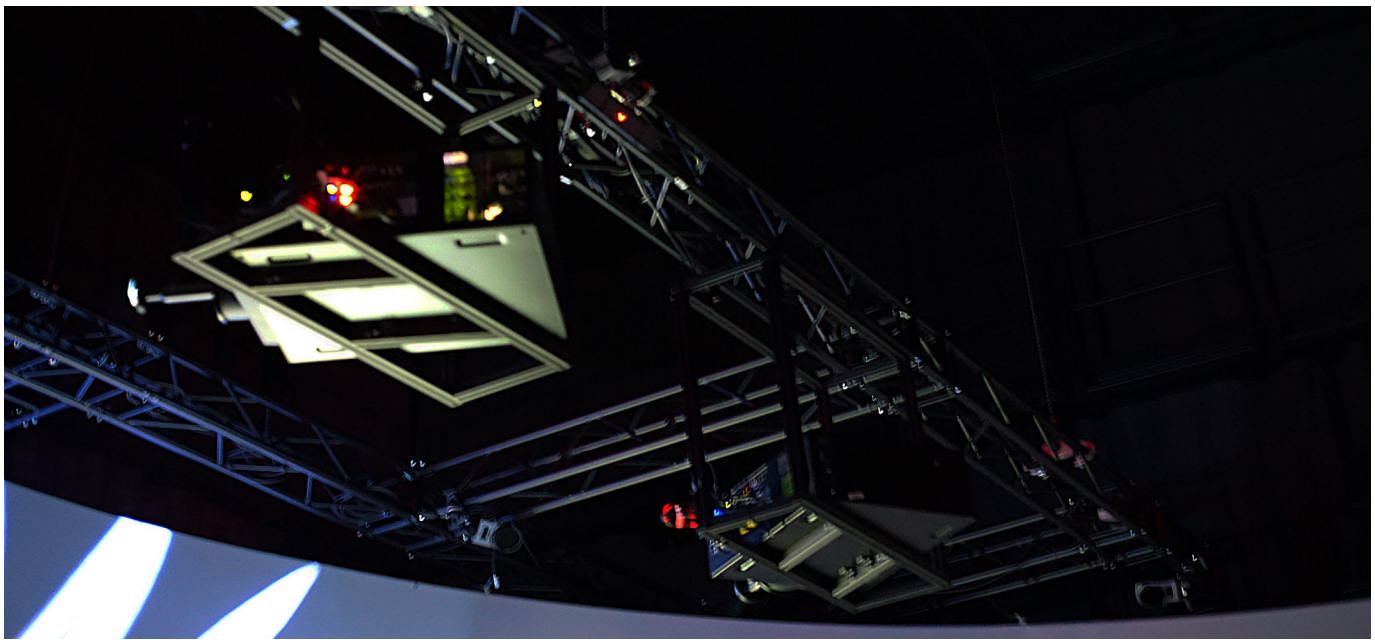

**Figure 9.1:** Dual projector setup attached to scaffolding above the Cyclorama.

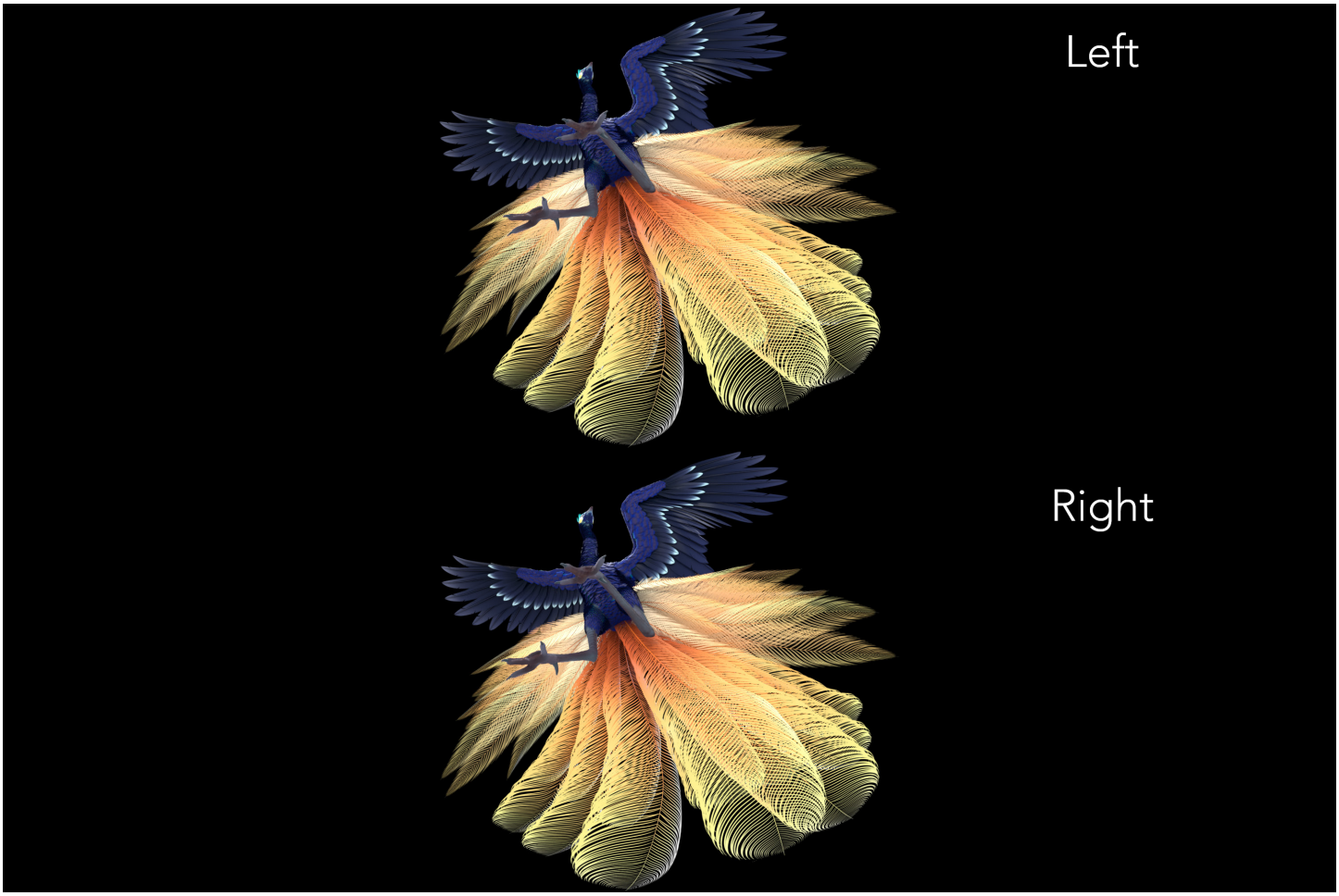


**Figure 9.2:** Phoenix stereoscopic example

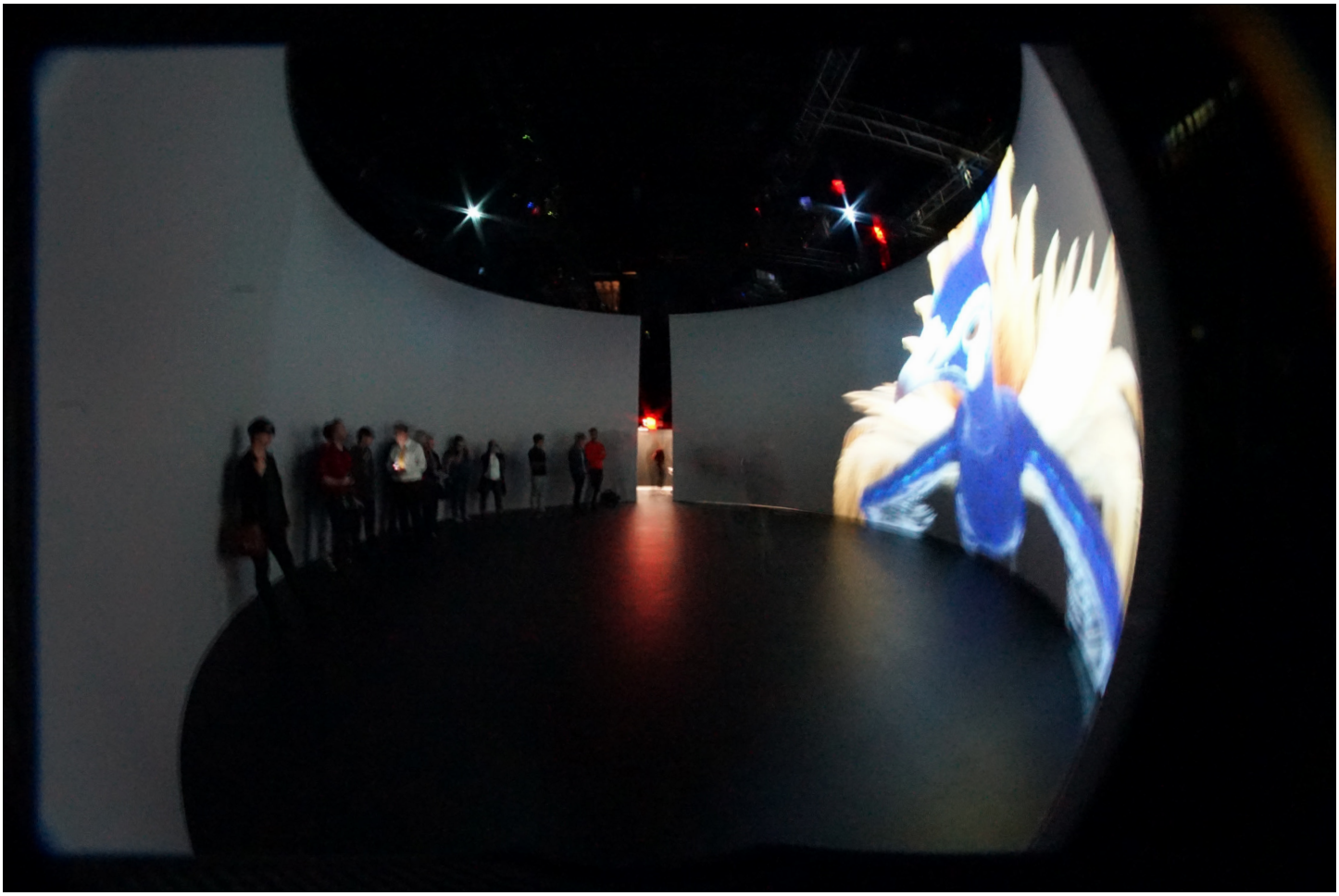

**Figure 9.3:** Stereoscopic Phoenix projected onto the Cyclorama

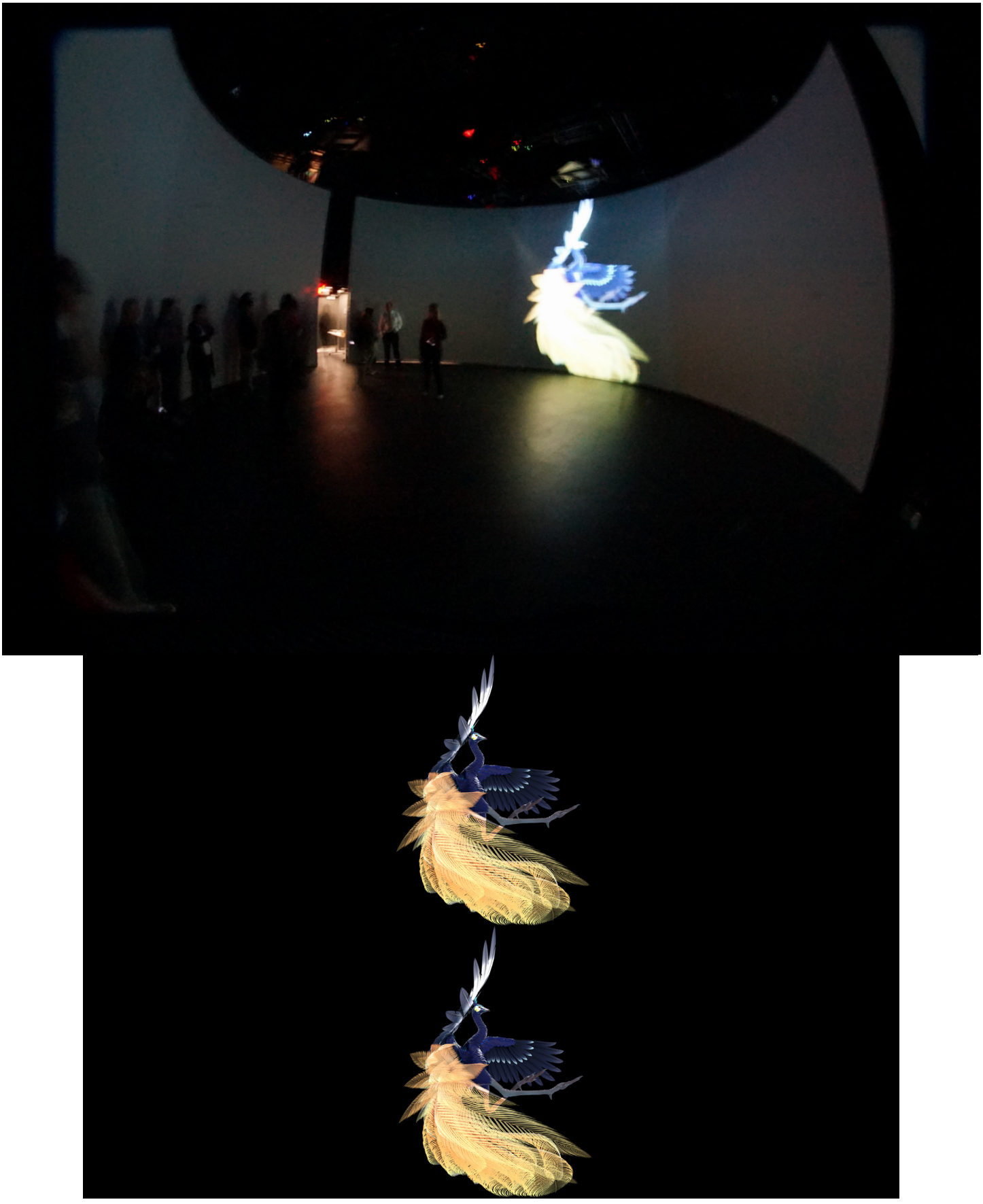

**Figure 9.4:** Top to bottom: Stereoscopic Phoenix projected onto the Cyclorama, and projected image with left and right eye