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Animated Film Production Process: The Creation of Lighting for Gear Up

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ANIMATED FILM PRODUCTION PROCESS: THE CREATION OF
LIGHTING FOR *Gear Up*

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Masters of Fine Arts
Digital Production Arts

by
Kevin Andrew Boggs
May 2016

Accepted by:
Dr. Jerry Tessendorf, Committee Chair
Dr. Timothy Davis
Professor Tony Penna

Abstract

The following thesis details the creation of a shot for an animated production titled *Gear Up*. The process for creating this shot was patterned after professional animated productions and included the following steps: pre-visualization, story boarding, modeling and asset creation, UV layouts, texturing and surfacing, scene assembly and camera layout, character and prop rigging, character animation, lighting, rendering, and compositing.

The motivation for this project was to create a product that artistically has a darker aesthetic than many previous Clemson DPA animations, but still enjoyed high quality visuals. One of the goals was to create a large-scale scene centered in a post apocalyptic robot war. This project also served as the first opportunity for incorporating the rendering engine called Arnold into the Clemson DPA animation pipeline and artist workflow.

In order to accomplish the goals set above, a series of technical and artistic problems needed to be solved. With the use of 3D preproduction prototyping, modular and procedural asset generation, new content generation tools, and optimized workflows, the team was able to tackle all production challenges and create high quality content efficiently and with minimal stress to the artists.

This thesis also delves into the elaborate process of scene lighting; detailing the artistic decisions and motivations that lead to the final product. The lighting is created by examining references from film and real life, lighting designs, and advanced lighting techniques.

The results of the project was a 400 frame animation of a post apocalyptic city block featuring a detailed robot, armed for war, standing guard by his tank amidst piles of debris, barbed wire, and rubble. The shot was rendered entirely in Arnold apart from the FX elements, which was rendered using Houdini Mantra. It also represents a successful collaboration between several volunteer artists with various skills and time commitments.

Dedication

I would like to dedicate this project to my parents Kris and Keith Boggs, and brother Kody Boggs. Without their love and support, and constant unwavering encouragement this project would not exist. I will always be sure to remember and live by my familys favorite quote: Do or do not. There is no try!

Acknowledgments

I would like to take the time and thank my committee members Dr. Jerry Tessendorf, Dr. Timothy Davis, and Professor Tony Penna for mentoring me throughout my career in Digital Production Arts. Their coursework in animation production, rendering and shading, theater, stage lighting, and global illumination has afforded me many opportunities to learn about lighting, production, art, and programming. They have unparalleled knowledge of their crafts and their support has proved invaluable during my time at Clemson. Their guidance has inspired me to pursue a career in CG Lighting and I will honor them by continuing to hold myself to the highest standards in every aspect of my life and career.

I would also like to thank all of my friends in the Digital Production Arts program at Clemson who volunteered their time to work on the project by helping to create the assets you see in the final product, attending weekly reviews, and providing critiques of my work. Without them, this project would not be what it is today. Thank you all for everything you have contributed and I sincerely appreciate everyone's help.

I would also like to thank the team members that helped out during the production. I sincerely appreciate all your help and hard work that went into the creation of *Gear Up*.

Adam Wentworth: Modeling, UV, Concept Art

Austin Brennan: Modeling

Cassidy Lamm: PA, Modeling, UV, Rigging

Christian Stith: FX, Animation

Dan Raitz: Modeling, UV, Concept Art

Erik Reed: Modeling, UV, Concept Art

Sarah Martin: Modeling, UV

S. Thaddaeus Wassynger: Modeling, UV, FX, Surfacing

Walt Fulbright: Modeling

Zach Shore: Modeling, UV, Surfacing, Pipeline

Nate Rose: Concept Art

Doug Rizeakos: Pipeline

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Chapter 1

Story Concept

For this production, the team wanted to challenge themselves to create a world that had not been explored yet in the Clemsons Digital Production Arts program. The tagline for the production was originally: In a post-apocalyptic city, robot soldiers patrol the streets for territory control. They participate in competitive and brutal warfare against each other in order to reclaim the objective, a scifi terminal sitting in the middle of the street. Though the logline provided a broad idea for the setting and story, it lacked key details that would be important for the project. In order to flesh out the story, the team needed to gather references and draw inspiration from films and games.

The story for the short was created with the intention to have a more action packed conflict in mind than previous animations at Clemson. This would include explosions, guns, and the death of the robotic characters. The story involved 3 teams of robots engaging in combat over a capture point terminal, a tall electronic beacon with a touch screen interface at the center of the intersection. The purpose of the capture point terminal went through several iterations throughout the story design. At first, the beacon was tied to humans controlling the robot characters from a safe distance. These humans would be using the robots as slave combatants, replacing real soldiers, in an effort to transfer money from one team to another through control of the terminal. It was also discussed that the robot battle would be treated more like an entertainment sport. The battle would be televised to viewers elsewhere, far away from the battle. The story was planned so that two teams would be revealed initially. Opening with one team on the ground in the process of capturing the objective, and a second team hiding in the parking deck preparing to strike. The parking deck team would use long-range sniper rifles to pick off a handful of the ground team. Out of thin air, a futuristic stealth



Figure 1.1: Scenes From Animatic

tank would appear and retaliate against the parking garage snipers, ultimately blowing away a large section of the building. In the end, a third party robot would appear from behind and take out the remaining ground team leaving the objective free for capture. A rough storyboard for this story arc can be seen in Figure 1.1.

The robot characters were designed like athletes in modern day sports. Areas of their armor would support team logos and color-coded internal components. Each team would represent a distinct faction and color style in order to make sure they could be easily identified in the scene. The story also included the detail that the first two teams of robots would be more up to date and in better condition than the third robot which would be rusted, have pieces missing, and have loose wires dangling. This was meant to allow the viewer to make comparisons between new and old, or potentially make a statement about large corporations who can afford the latest and greatest vs local organizations who struggle to scrape together something that just barely works, but was more effective in the end.

The setting was planned to be a warzone with the architecture and environment styles mimicking what could be seen in a modern day city. The environment would be treated as if the warzone was roped off in an older part of the city that was obsolete and scheduled for demolition.



Figure 1.2: Halo 3 Capture the Flag Reference [BM07]

It would be an area where anything goes and only slight elements of past life can be detected in the store signs and boarded up windows. Rubble would be piled up to obstruct lines of sight, and military supplies and destruction elements would provide a stark contrast for an otherwise normal city intersection.

The art style and story of the project was heavily influenced by video games. For example, the concepts for the characters objective was similar to a common multiplayer game mode, capture the flag. This objective style game mode appears in several games including Halo 3, pictured in Figure 1.2, and depicts 2 teams, one red and the other blue battling over control of a flag similarly to the robot characters battling for control of the capture point terminal [BM07]. Additional artistic styles for the characters were inspired from Destiny, a science fiction first person shooter. The concept art from Destiny pictured in Figure 1.3 helped to influence elements of the characters body especially the head styles [LK14].

Due to limited time and artists available, the final product was just a single establishing shot. This allowed the team to focus on achieving a high level of visual quality. Even though the other shots in the story were not continued, the team continued to generate assets and prepare each stage of the pipeline as if they were still planning to complete all of the shots. This meant



Figure 1.3: Destiny Concept Art [LK14]

that each stage of the pipeline was handled in a way that stressed optimization, reusability, and modular design. In the end, the project contained all of the assets needed to make the full story. The following chapter provides an introduction to all major stages of the pipeline, and how the team tackled the difficult obstacles that arose in each.

Chapter 2

Stages Of The Animation Pipeline

The stages of the animation pipeline contain several sections detailing where different work for the production takes place. While the overall composition of each section varies based on the studio and the production, a set number of stages can be consistently mapped including: pre-visualization and storyboarding, modeling, UV Layout, rigging, Layout, Animation, FX, Lighting, and Compositing. The following sections will serve to give the reader a brief overview of what each section includes and how each section was tackled in this production.

2.1 Preproduction / Storyboarding

Traditionally, the process of storyboarding and pre-visualization had mainly been accomplished with hand drawn media, either through pencil and paper or digital tools such as Photoshop. This allowed an artist to quickly iterate on an idea without weighing down the production with unnecessary tasks. The driving factor for how useful this approach was depends entirely on the skill of the artist and the speed at which they could work. For this project, a hybrid approach worked the best. A result comparable to the alternate hand drawn method was able to be achieved by using a mixture of 3D temp assets and open source models to block out the shots, combined with detailed image diagrams of set pieces, broader scene sketches, and photo references.

The result of the 3D blocking can be seen in Figure 2.1. This served as a starting point for artists to understand the story and its elements and provided the team with a model of the scene early on. Once the storyboards were assembled in 3D, making iterations on them were quick and



Figure 2.1: 3D Model Scene Blocking in Maya for Preproduction and Storyboarding

painless. It also provided useful technical information in regards to scene scale and object scale that were invaluable in the modeling process. Proxy objects such as the character, buildings, and set pieces like the tank, were exported and re-used in the modeling stage for scale reference. This ensured that all models were created with proper proportions and there would be no need to go back and correct any issues with object scaling in the later stages of production.

Detailed diagrams for the important objects in the story such as the character, weaponry, and vehicles were also created and iterated on in 2D. The diagrams listed in Figure 2.2 depict the detailed view of the base robot character with alternate head styles to differentiate characters. Diagrams of the characters weaponry were also created as shown in Figure 2.3. These diagrams were imported into the model file and set up as image planes so that the artist could use them as reference during asset creation. Additionally, detailed sketches for parts of the set were created in order to spark creativity and set the artistic tones that were used throughout the production process, specifically on objects that had no photo reference. Some of these images can be seen in Figure 2.4 where the style of the capture point terminal was fleshed out.

It is important to note that the hybrid approach was not perfect. It did not cover every detail that would be needed to create the feeling of a destroyed city block, but it did provide a quick starting point for brainstorming a list of elements that were missing from the scene. Objects were organized in terms of reusability, ease of creation, and importance to the story. From there, reference images were found for each object that would also serve as artistic guidance for the project. For

Artist: Adam

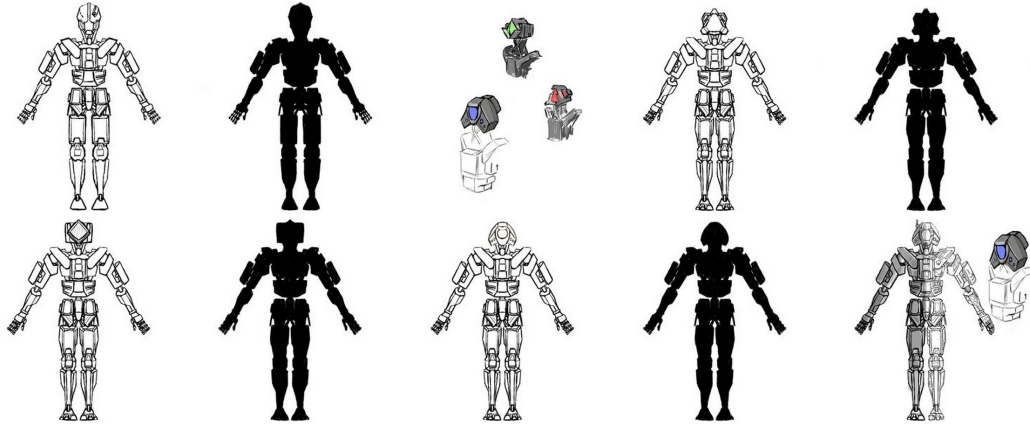


Figure 2.2: Robot Designs

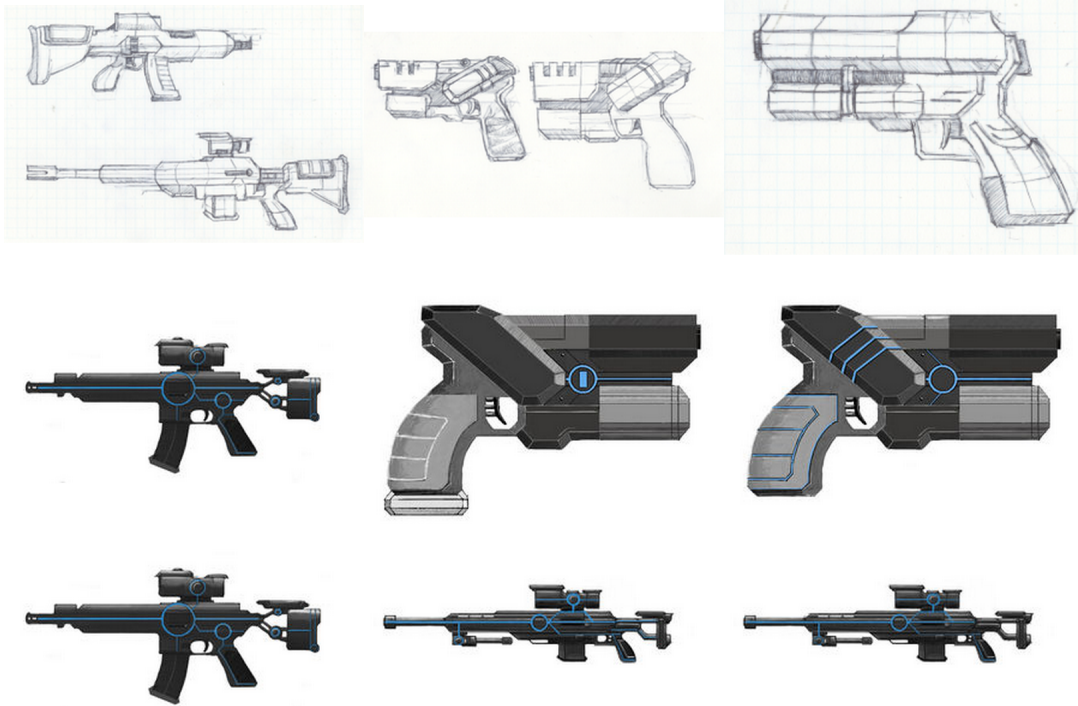


Figure 2.3: Weapon Designs

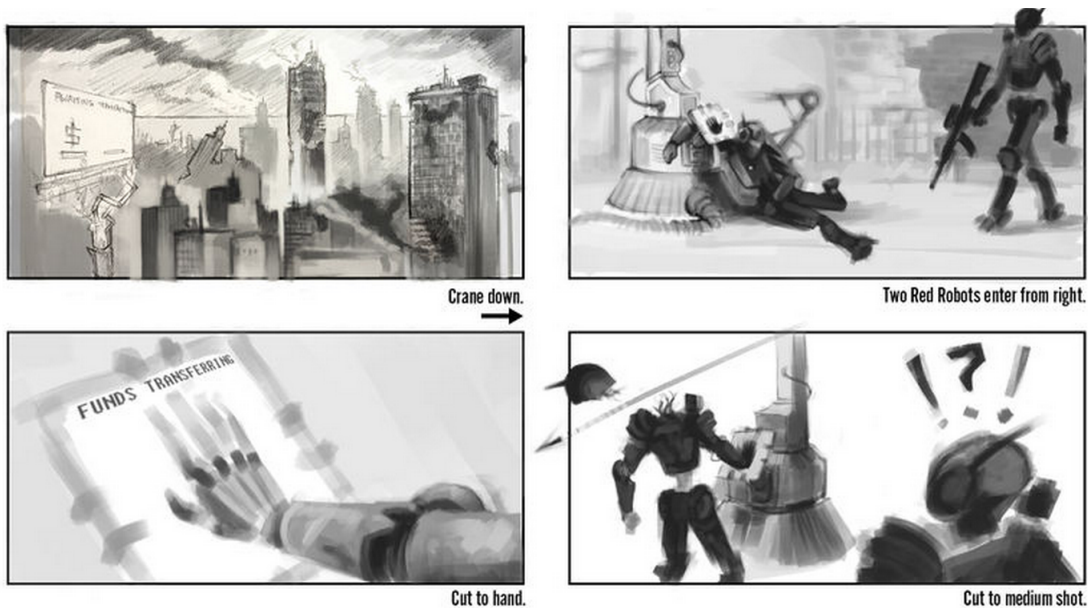


Figure 2.4: Capture Point Terminal Concept

example, the image in Figure 2.5 proved extremely useful in influencing the building facade style and models [MM12].

This approach to preproduction and storyboarding proved extremely useful. It allowed for quick iteration of shots and easy experimentation with different layouts in the scene with minimal artistic effort in 3D. Electing to create 3D proxy objects allowed for scene scale to be determined early on and guide objects to be created that aided the other stages of production, saving an untold number of hours in revision. It also gave the 2D artists more time to focus on designing set pieces and image planes for modeling. Any elements that were not directly addressed in either of the two methods were identified and reference images were found for all objects.

2.2 Modeling

In the modeling stage of the animation pipeline, the 3D model assets were created. Thanks to the success of the preproduction stage, questions of scene and object scale were already decided and diagrams had been created by other artists for set pieces. A list of environment models and set pieces complete with reference images was also created. However, the task of creating high quality 3D models with professional detail was not a simple process. When looking at the model list, it



Figure 2.5: Building Facade Reference [MM12]

was clear that something needed to be done to consolidate the workload without compromising the visual goal of the project. Models were grouped into categories of large-scale and small-scale environment objects. In addition to categorizing the objects, a 2-step plan was defined to maximize model reusability while minimizing artist effort. This plan featured a mixture of modular model creation and procedural asset generation.

Any objects that were large in size such as buildings, building facades, sidewalks, and debris piles would be considered large-scale environment objects. These objects would be more challenging and time consuming to generate. This list would also include many of the objects that would be the most integral to the story and would require more iteration. The small-scale models were categorized by objects in the environment that would appear multiple times, would be less modeling intensive, and would help give the set characteristics of a war torn city. By separating these assets from the others, it allowed for better time management and scheduling.

It would be a daunting task to have artists model an entire city by hand. With a small team of volunteers, with varying experience with 3D modeling, it would be impossible. In order to maximize the amount of usable content generated and minimize artist workload. It was decided that a modular system of generating models would be used, specifically for hand crafted models. This technique has been used in feature films on larger scales. For example in, *Cloudy With a Chance of Meatballs 2*, the entire fictional city of San Franjose was modeled and created with only a few base building models [Son13] [nur13]. Each model was designed in such a way that allowed them to be rotated, scaled, rearranged, and stacked on top of each other in order to create enough variation

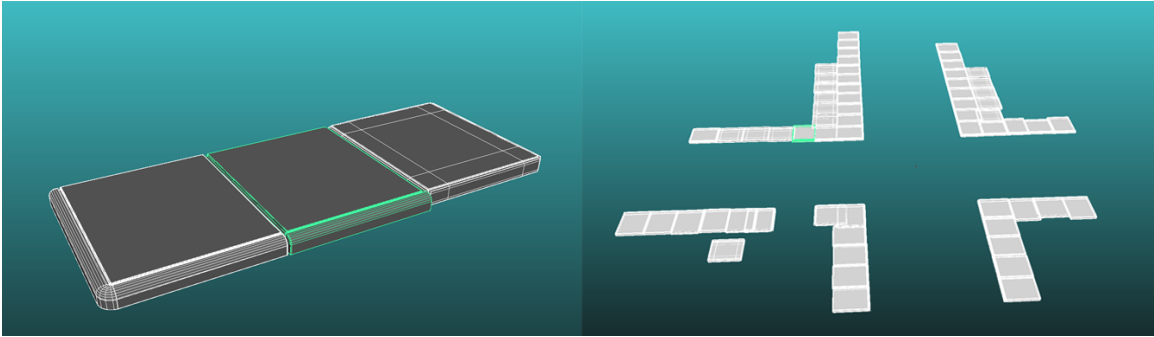


Figure 2.6: Sidewalk Models

and gave the illusion that the entire city was unique. Instead of creating whole buildings for *Gear Up*, the team decided that a series of 6 building facades would be used to create the illusion of variation. These buildings would be hand modeled to ensure that the foreground and mid-ground of the scene would contain enough high quality, model detail. Other elements of the scene were given the same treatment whenever possible. For example, the city sidewalks were created from 3 different pieces including a corner piece, end piece, and a center piece pictured in Figure 2.6. This 3-piece set was assembled into a collection which kept the models together throughout the modeling and surfacing stages of the pipeline. This allowed them to be imported in bulk in the layout stage and assembled, similarly to Lego pieces, to form the sidewalks seen in the final product. Other collections were created as well for window designs, debris and rubble piles, and the main bodies of buildings. Keeping objects together in collections saved time when pushing dozens of assets through the pipeline from one stage to another. This system was flexible enough that it gave artists the ability to optimize their scene depending on their task by hiding objects that were not needed.

Even though modular asset generation decreased the amount of work for the artist and maximized the reusability of a model, it still required that an artist model by hand. For all of the assets that were too difficult to be modeled by hand in a reasonable amount of time, a procedural modeling approach was taken. For example, the background buildings in the scene pictured in Figure 2.7 were generated by other FX artists on the team using Houdini based off of a single polygon plane indicating the base size and shape that the building should take. Attributes like window size, shape, and floor height were customizable and allowed for a wide variety of background buildings to be created to give the scene variety and a grand scale. Another example of procedural modeling is the barbed wire present throughout the scene which can be seen in Figure 2.8. This detailed

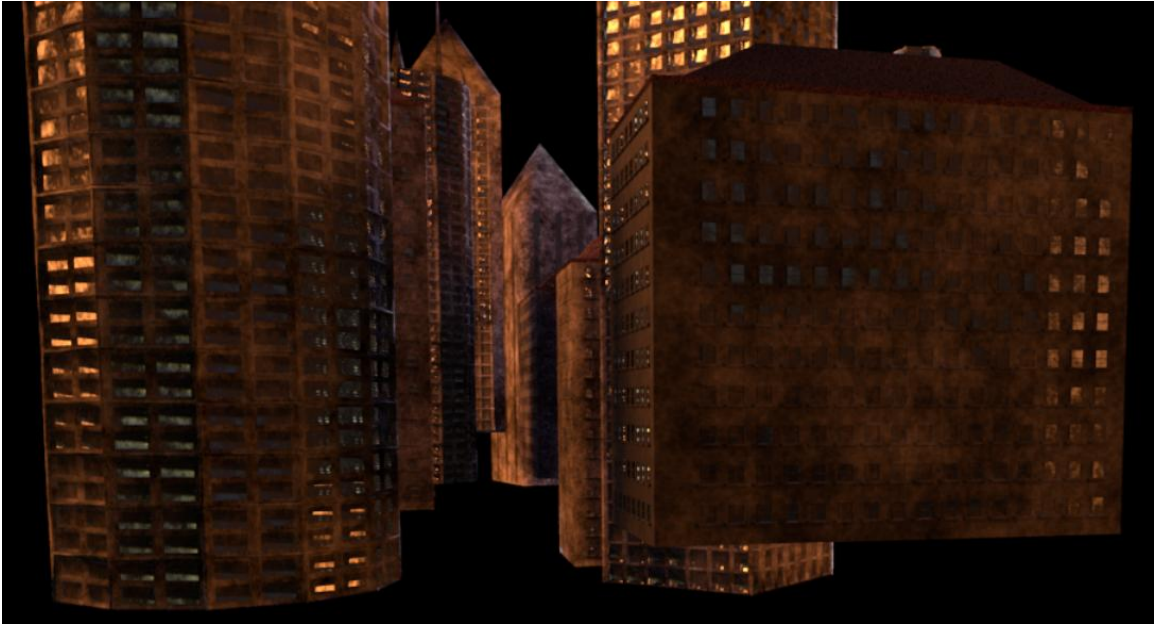


Figure 2.7: Background Buildings

object would have been difficult to create by hand as they needed to be attached to the military roadblocks scattered throughout the scene. The location for the roadblocks was not decided until the layout stage much later in the project and would have caused the barbed wire to be remodeled causing significant delays. By generating the coils of barbed wire procedurally, the FX artist was able to import the locations of the road barriers from layout and easily place them in the appropriate positions as well as update their placement with minimal effort.

For all other assets in the scene an effort was made to avoid wasting time on one-off models. Instead, models that could occur multiple times in the scene like cement roadblocks, fire hydrants, dumpsters, sand bags, and street lamps were created. These assets helped to fill the scene and give it characteristics of a war torn post apocalyptic city. Large-scale debris was modeled and sculpted using Mudbox for the background in order to obstruct the horizon of the scene and helped add another layer of destruction.

With the careful planning and the use of procedural techniques, the 3D models for the project were created in 12 weeks. More importantly, the team was able to hit the visual target and level of detail required for the project.

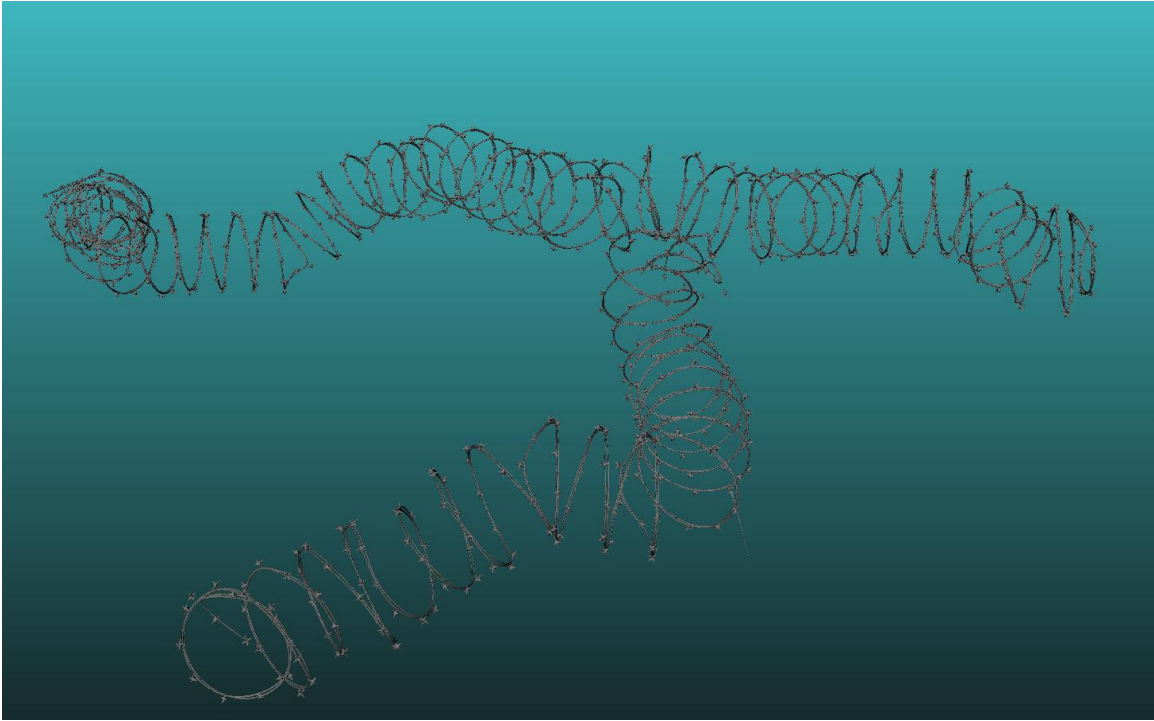


Figure 2.8: Barbed Wire

2.3 UV Layout

It was essential to this production that every model had a correct and functional UV layout. With the large volume of models, adopting new UV techniques and tools was key to creating successful UV layouts in a short amount of time. A large portion of the assets were UVed using Autodesk Maya's built in tools. While Maya had a robust set of UV tools, they were not perfect by any means. In order to speed up artist workflows, a simple Maya python script with commonly used tools and hotkeys was created and distributed to the team. This made navigating and selecting UV shells fast and provided quick access to more difficult tasks that were buried in the user interface like transferring UVs from one object to another. Even with the helpful hotkey scripts, UVing in Maya was still a struggle, especially, for any object with significant amounts of complexity such as the base robot character and stealth tank. For these objects, the team adopted a different workflow and a new tool.

A collection of complex models were UVed using the free trial version of Headus UVLayout, a stand alone application for the creation and editing of UV texture coordinates for 3D polymeshes and

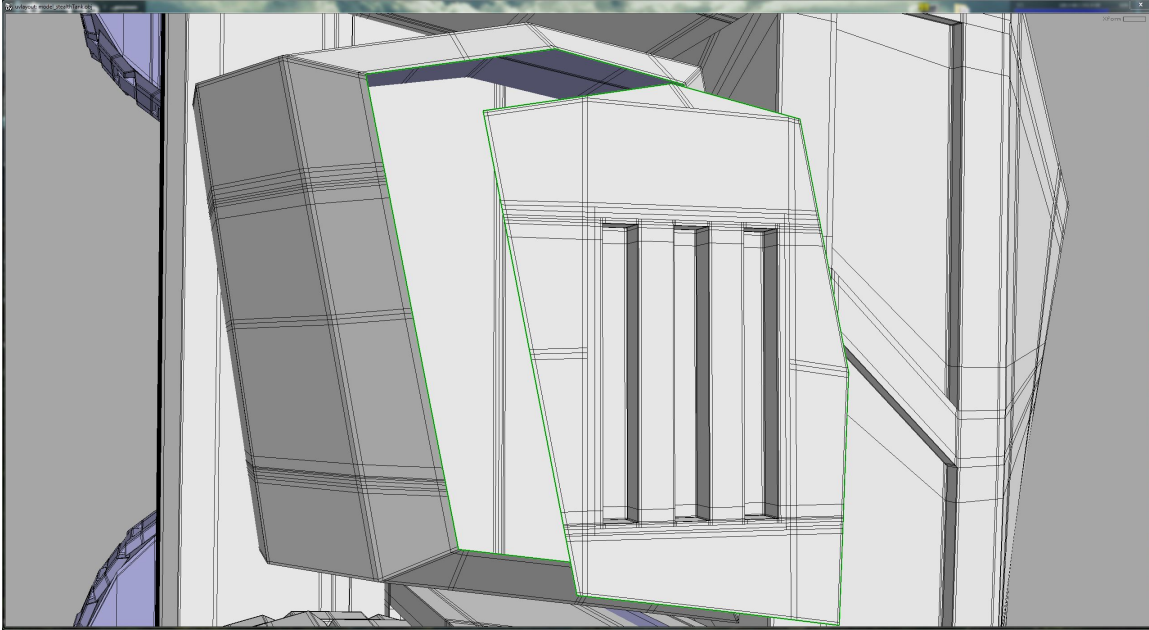


Figure 2.9: Cutting Tank UV in Headus

subdivision surfaces [hea10]. Headus is available on all major operating systems. The main benefit of using Headus over Maya's built in UV tools was the improved visualization of the UV process, and better performance of common operations like unfolding and smoothing. Headus sported several features that allowed seams to be created on complex surfaces extremely quickly, which would otherwise be more difficult to do in Maya. It also had a better visualization of separate UV shells. For example, in Figure 2.9 a section of the tank geometry has been separated from the base mesh with a cut, and in the 3D viewport, the shell was visually detached from the rest of the model automatically. This useful display feature does not exist in Maya and provided the artist with an accurate representation of how their changes were affecting the UV layout. The software also had unfold and smooth tools that performed much better than what was present in the version of Maya currently available at Clemson. When unfolding, Headus produced a better result quicker and also had a color-coded representation UV texture space. These colors highlight areas where textures were being stretched and areas where texture resolution could be increased to prevent pixelation. An example of the tank UV layout can be seen in Figure 2.10 where the majority of the UVs were colored green representing a healthy balance of texture space based on the size of the polygon.

It is important to note that while Headus provided a great collection of tools to speed up

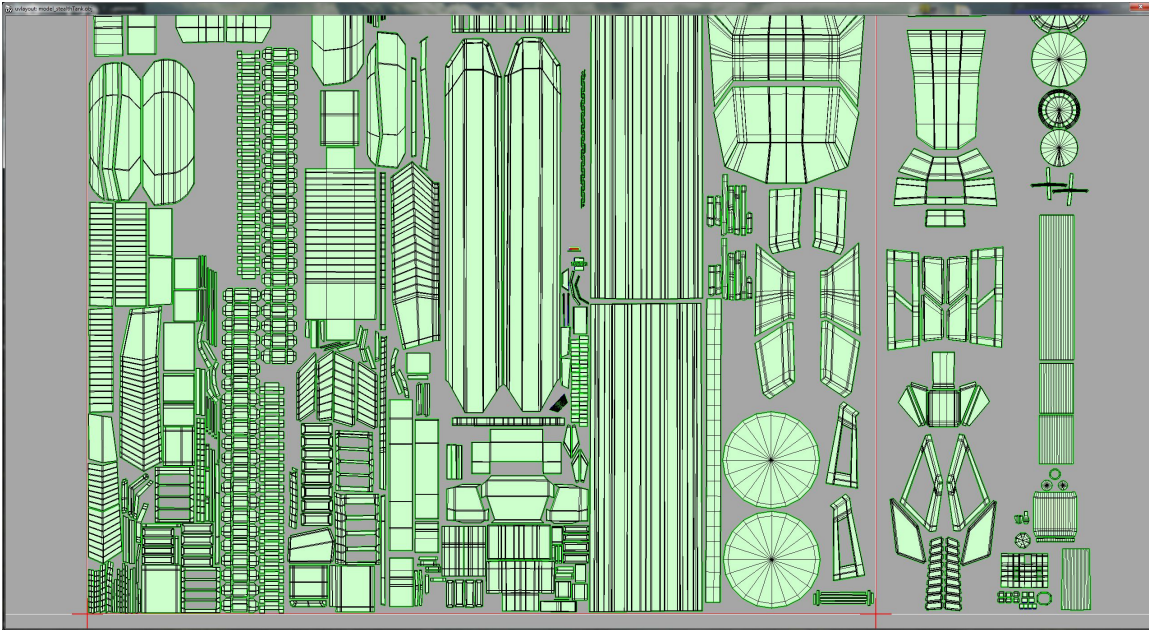


Figure 2.10: Tank UV Layout in Headus

the modeling artist's UV workflow, it did nothing to make sure that the UVs were laid out correctly and that seams were cut smartly. This meant that no matter how good the content creation tool was, it would always be limited to the skill level of the artist. In order to give modelers knowledge of good UV practices, each person was tasked with modeling at least one complex object manually using Maya's built in tools and having their work reviewed, making sure that a good foundation was emphasized.

This production attempted to innovate on the past process of UV generation by experimenting with new tools and enforcing strict standards for UV quality in every model. Using these techniques the team was able to rapidly complete the difficult task of creating UV layouts for the large volume of objects in the production. All models were able to receive a successful first pass in less than 12 days. In comparison, it took the team several weeks to create the same amount of models used for the project. Hopefully, in the future, Clemson's Digital Production Arts Program will continue to incorporate Headus into the production pipeline and work to further optimize UV workflows.

2.4 Surfacing

During the surfacing stage of the animation pipeline, materials and textures were applied to every object in the production. Materials were determined by an object's shader properties. Textures were image maps that drive shader properties and were created by an artist by hand or using procedural nodes. When combined together, materials and textures give objects color and life. The options for shaders depends entirely on the rendering engine the software supports. For example, Autodesk Maya has 2 rendering engines that come with it: the standard Maya Software renderer and the Mental Ray renderer. Additionally, past animations at Clemson have used Pixar's Renderman as the primary renderer, but, for this project, the team was challenged to work with a new renderer called Arnold. Currently developed and maintained by Solid Angle, Arnold is an advanced Monte Carlo global illumination renderer built for the demands of feature-length animation and visual effects. Originally co-developed with Sony Pictures. Arnold is used at over 300 studios worldwide. Arnold is the primary renderer on dozens of films from *Cloudy with a Chance of Meatballs 2* and *Hotel Transylvania* to *Gravity* and *Pacific Rim* [Ang16e]. Adopting a new renderer was not an easy task since almost all aspects of the production process including basic pipeline functionality and artist workflow had to be re-worked and re-learned.

For example, in order to prepare the pipeline for Arnold, several tools needed to be updated by the team's pipeline engineer. The pipeline queue submission tool, *The Dark Knight*, need substantial edits to support Arnold's rendering command called *kick*, as well as Arnold's native scene description file format called Arnold Scene Source also known as *.ass* files. The Surfacing texture map import tool needed to be updated to support Arnold's custom UDIM tokens, which differed from Renderman UDIM tokens. On top of that artist workflows for rendering and render settings, lighting, surfacing and shader creation, had to be relearned from scratch. Tasks that artist's already knew how to do in Renderman did not always transfer over to Arnold. Some examples include rendering depth passes and AOVs, controlling the quality of renders, debugging rendering artifacts specific to Arnold, light linking, using different shader types with varying levels of physically based parameters, and even creating attribute overrides. While these individually are not very difficult problems to solve, together they added up and created large challenges that hindered progress. One specific example was the discovery of how Arnold does subdivisions. When assigning displacement maps to surfaces, the surfacing artist set the shape node of the object to have Catmull Clark sub-

divisions with 4 iterations and each subdivision iteration quadrupled the number of polygons on an object. Additionally if Maya's 3 key smooth option was used during render time, Arnold would apply an additional 2 levels of subdivision to the object. This meant that dozens of objects were being subdivided 6 times, resulting in the polygon count and render time to skyrocket and computers to crash. The pipeline engineer increased the verbosity of the error output in the .ass files generated by The Dark Knight, and the artist was able to see the problem and find the fix by setting the max subdivision count override in the render settings from 9999 to 4.

Due to the short surfacing schedule, demand for high quality visuals, and large volume of model assets needing to be shaded, past methods of surfacing had to be optimized. The team could not afford to hand paint each asset in hero quality detail one at a time because other departments needed to work with the assets while they were being surfaced. Similar to the modeling stage, surfacing was handled in a 2-step approach that involved manually painting texture maps using Mari and creating procedural-shading networks that could be customizable by the artist in Maya. These techniques would serve to provide enough variation and detail to meet the desired visual goal.

The first step the team took to tackle the massive task of surfacing was to apply a base shader to all objects depending on its material type and pass it through to the next stage of pipeline so that surfacing would not hold up production in other areas. In order to do this, the team needed to learn how Arnold shaders work and what parameters would need to be adjusted based on the surface type. Luckily, Solid Angle had detailed documentation for the Arnold shading process and by using the reference found at [Ang16c], a file was created with a collection of base template shaders seen in Figure 2.11. This template file was then imported into each new surfacing file so that the artist could quickly and easily copy a base shader they needed without having to manually create them each time. With this workflow, every object in the scene received an initial shader pass in less than 2 days. Assigning base shaders to all objects as a first pass and pushing them through pipeline increased productivity for all stages of the pipeline and ensured that the time consuming portions of pipeline management such as creating subscriptions and exporting assets were set up and functioning properly.

Hand crafted artistic maps were painted using Mari, a 3D content creation tool that allowed the artist to paint textures using brushes by hand or using high resolution images from online resources. One of the powerful features of Mari was that the artist had the option for painting maps on the UVs of a model or directly on the mesh with its projection tools. Texture sources



Figure 2.11: Base Arnold Shader Presets [Ang16c]



Figure 2.12: Parking Deck Surface

were collected from online resources like CGTextures.com [tex05] and joostvanhoutte.com/textures/[Van16b]. A large library of high-resolution open source textures was compiled and could be accessed in the textureGen product in pipeline so that they could be used for future projects at Clemson. In addition to hand painting textures on the models, artists made use of Mari's powerful procedural nodes to add quick and easy variation to an entire surface whenever possible. An example of this can be seen in the parking deck surface pictured in Figure 2.12. By using Mari's procedural tools in conjunction with texture map sources and hand painted elements created with the wide collection of built in organic brushes, the surfacing artist achieved a detailed and varied result in half the time it would have taken to painting the model by hand. Reaching a good result faster allowed for more iteration on the surface and helped to increase the quality of the end result.

Hand painted textures can only go as far as the artist's skill and with a strict surfacing time constraint an alternate surfacing scheme needed to be explored. That was where procedural shader networks came in. For surfaces, like metal, that populated dozens of assets of the scene, a system for creating variation and visual interest in the surface was created. The procedural shaders were developed by other members of the team and implemented by the surfacing artist. One example of this was a procedural rust shader that was created and added to the base shader library mentioned



Figure 2.13: Procedural Shader Before and After

above. This shader allowed artists to attach texture maps to drive the pattern, scale, the intensity of the rust as well as integrate the material with other shaders containing artist painted maps. This allowed for an additional layer of destruction and decay to be added to an objects surface instantly. The speed of use and the amount of customizable controls resulted in an incredible increase in visual interest in objects surfaces. This change can be seen in Figure 2.13 when comparing the military roadblock with just the base shader and with the procedural shader. The procedural shader was also applied to assets that were small or far away from the camera. Using the procedural shader on those objects allowed texture artists to better optimize their workflow and gave them more time to iterate on other objects in the scene that needed more attention.

2.5 Rigging

For this project, the objects that needed to be rigged were defined in the preproduction stage, and the pipeline was organized in such a way that would indicate the type of rig needed for each object. The character was prepared in a character generation pipeline asset called charGen and all props and vehicles would be stored in an area called propGen. This meant that the artists would not need to struggle when trying to find assets that needed to be rigged.

The character posed several rigging challenges. For starters, it did not fit the usual build

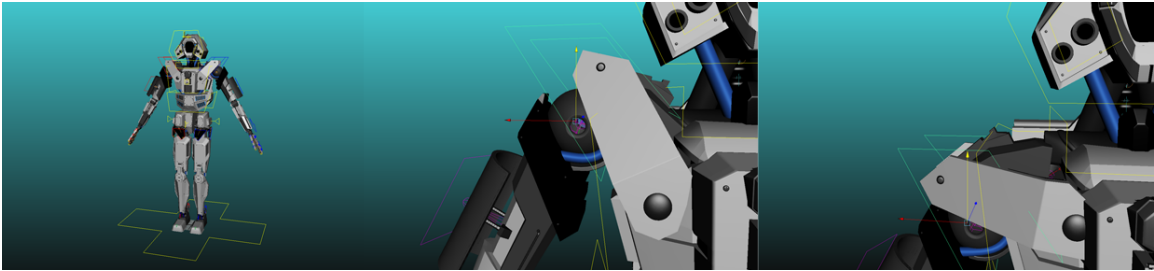


Figure 2.14: Robot Shoulder

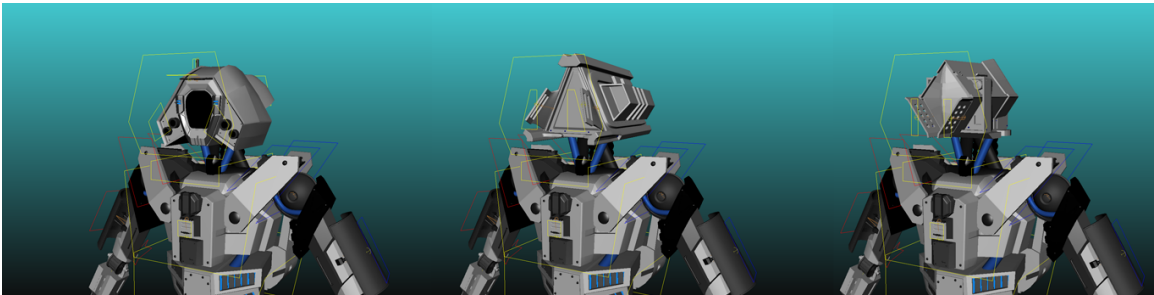


Figure 2.15: Robot Head Collection Models

for a humanoid character. The additions of extra points of articulation around the shoulder area for example pictured in Figure 2.14 allowed the character to hit poses that would otherwise be impossible for a normal human. The rigging artist had to plan out the joint locations in advance to accommodate for these differences and make the character movements as robust as possible. There was also a need for the character's body model to be repurposed, and 3 separate styles of heads needed to be interchangeable in order to differentiate protagonist and antagonists in the scene. It was decided that the easiest way to do so was to give the artist the ability to switch between the heads in one rig rather than having to create 3 different character rigs. There was no point in recreating 3 separate rigs when the body model was identical on each character. The result can be seen in Figure 2.15. A single rigging artist created the main robot rig, and other team members added small corrections and optimizations.

Another challenge of the character rig was that the polygon count for the mesh was very high due to the amount of detail included on each piece. This would pose problems in animation due to the delay in the software when moving the controls. One solution, to increase performance and decrease the slowdown in animation, was to animate the character in an unsmoothed form. This

drastically increased efficiency and artist productivity, but an additional layer was added to the rig to help even more. Proxy geometry was created that roughly matched the character model and was parented to the rig. This minimalist blocking, pictured in Figure 2.16, allowed the artist to hide the base mesh of the character entirely in order to rapidly increase productivity when animating.

Additional problems appeared when updating the surfacing file of an already skinned object, resulting in the rig file breaking. The issue occurred when the Arnold shader attached to the surface file was replaced later in production. When the artist rigged an object and applied skin weights, a new deformed shape node was created and was pointed to the shader previously attached in the surfacing stage. This is demonstrated in Figure 2.17 where the original shape node was connected to the shader as well as the new deformed shape node. When updating to the new surface file in the rigging stage, the new surface contained the information about the original shape node but not the deformed shape node. When Maya attempted to merge the new referenced shader information with the edits made in the rig file locally, it did not know what to do with the deformed shape node as it was no longer connected to the old shader. The result was a broken connection and is shown at the bottom of Figure 2.17. The artist had the option to reload the reference of the surface file, but this step was not ideal and would remove the skin weights from the rig. In order to fix this problem without loss of work, the rigging artist had to manually reconnect the shape-deformed node to the shading group with the new shader attached. This fix can be seen in Figure 2.18. The reason this issue has not presented itself in past productions was due to the fact that shaders usually were never replaced after an object had passed to rigging. This turned into a common problem for objects that were passed to rigging early and needed shader corrections like the character and the tank.

Prop rigging was used for assets that the character would need to interact with including the characters weaponry pictured in Figure 2.19 as well as other aspects of the environment that might need to be animated at some point in the story such as the tank pictured in Figure 2.20. The important aspects of a successful prop rig were that it needed to be robust and animator friendly. For example, the assault rifle had to be held by the character and so a specific area of the rig was cleared out specifically for parent constraining. This gave the animator the ability to constrain the gun to the palm of the robot without breaking other constraints present in the character rig. Constraining the assault rifle to the palm allowed the prop to follow the characters movements without the animator having to do any offset keyframes. To enhance the functionality, the props were rigged so that the animator had the option to shift the prop in the character's hand in order

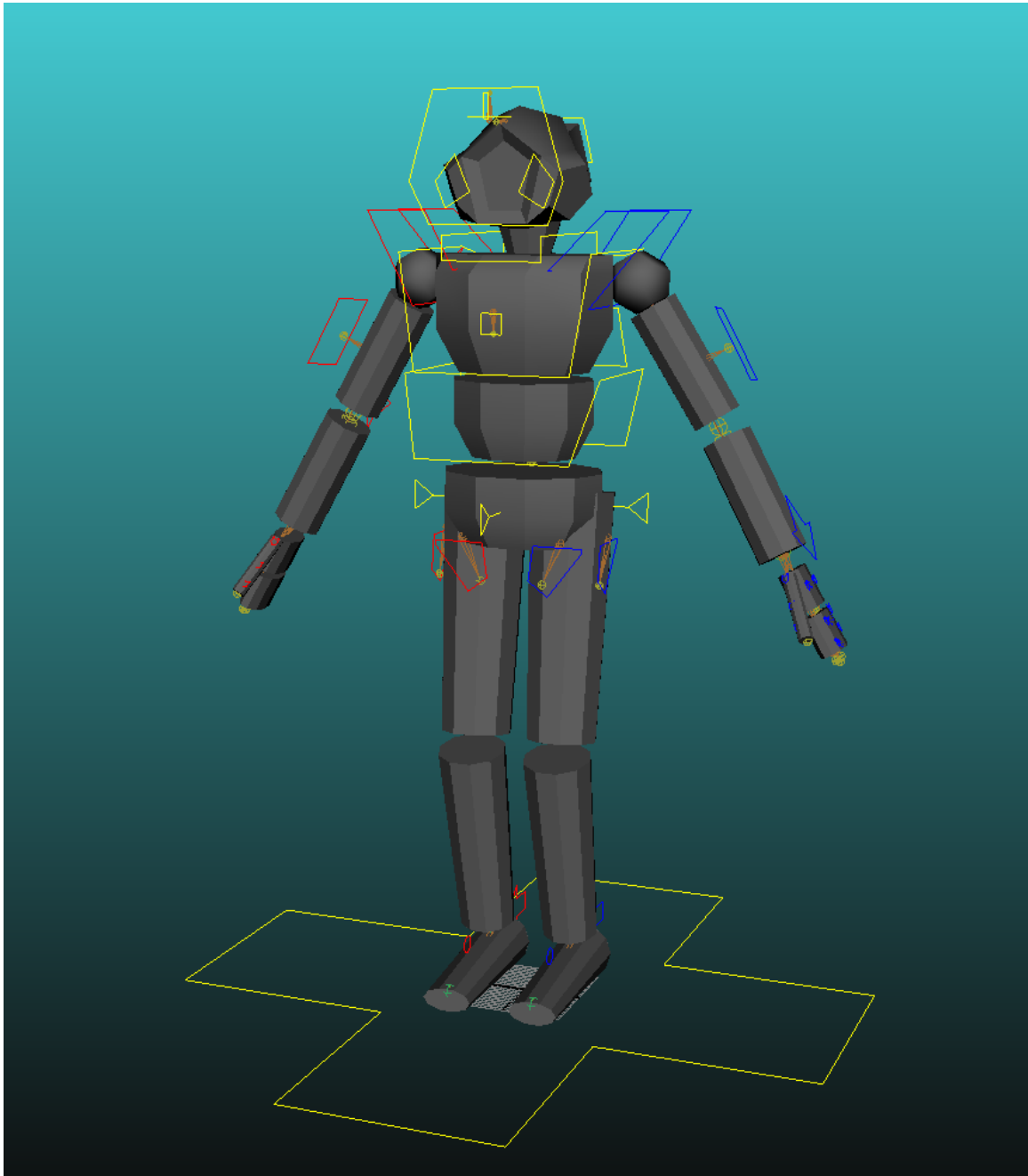


Figure 2.16: Robot Proxy Rig

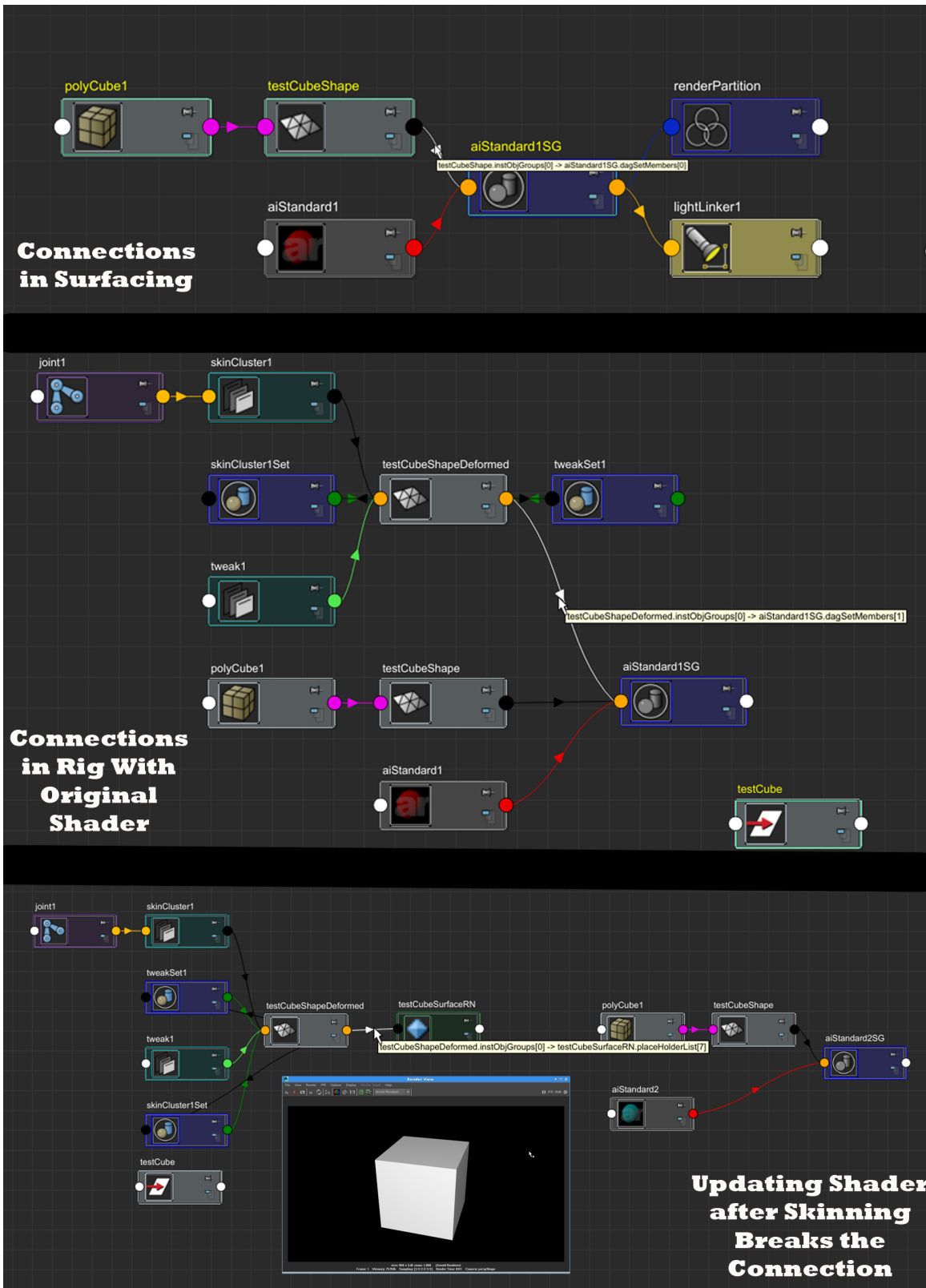


Figure 2.17: What Happens When a Shader is Changed in Surfacing After a Model Has Been Rigged

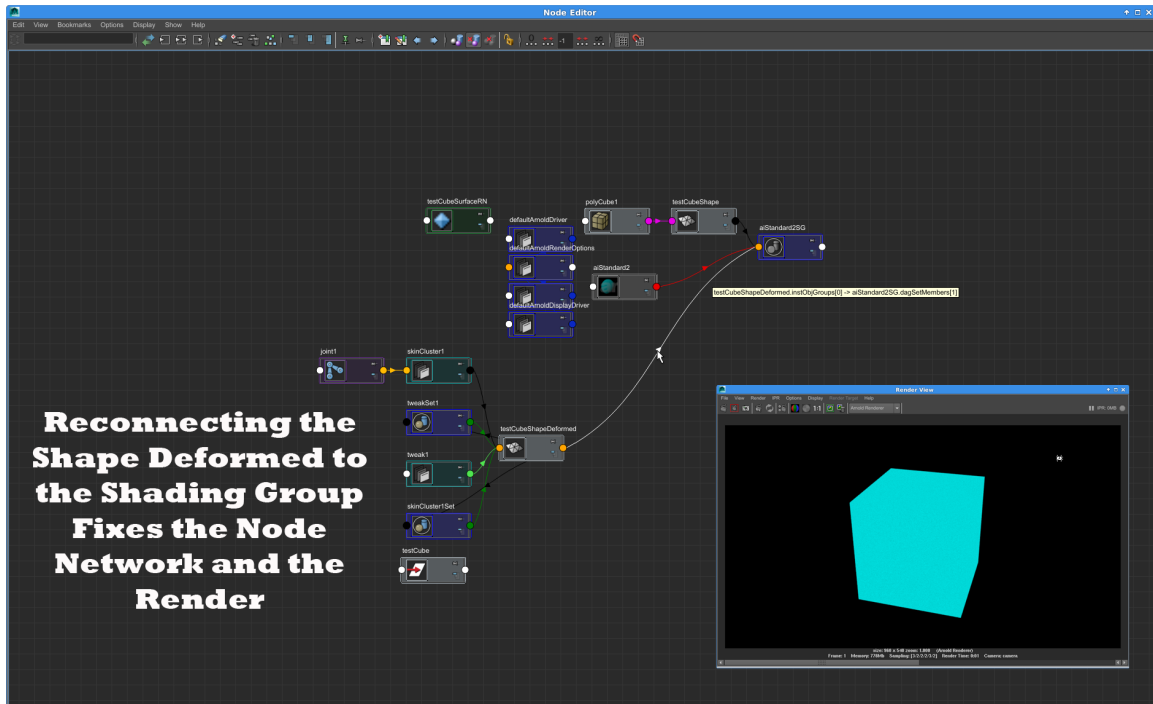


Figure 2.18: Broken Connection Fixed

to add secondary motion. This motion would be completely separate from the rest of the characters motion and serve as an extra layer of detail in the animation.

Like any piece of art, the rigs for the production were iteratively improved on until they were able to handle any task the animation artists could throw at them. The end result was a collection of character and prop rigs that were robust, configurable, optimized and had the ability to support several different animation styles.

2.6 Layout

Layout is the stage of the animation pipeline where camera attributes and animation is finalized and locked down. Using the work from preproduction as reference the layout artists assemble the scenes, block rough animation for the shots and focus on refining camera angles, focal lengths, lens types and camera movements. For this project, the layout stage focused on camera settings and animations, as well as organizing and assembling the separate modular components of the set into a single reusable scene.



Figure 2.19: Prop Rig

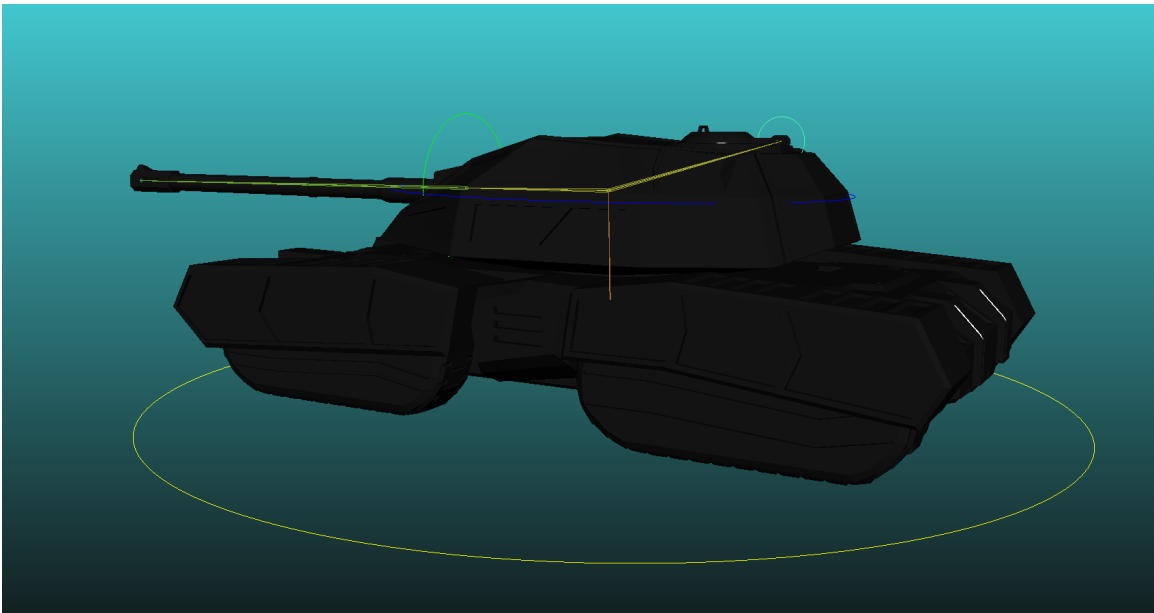


Figure 2.20: Tank Rig

When selecting a type of camera the layout artist needed to take a look at the list of goals for the production. The main elements that need to be achieved were the grand scale of the scene and that it needed to look like a war torn city. Initial iterations of the camera for the shot did not take camera lens type and positions into too much consideration. This caused the scene scale to look drastically smaller and less like a city and more like a small hand made miniature. In order to correct this, the camera was moved closer to the ground and angled slightly up in the vertical axis creating a low angle shot. Typically low angle shots help to create the psychological feeling of objects being large, strong, and powerful [Sul16] [Mam09].

Another change that was made to the camera was that the focal length was decreased from 25 to 18. The focal length tells us the angle of view, how much of the scene will be captured, the magnification, and how large individual elements will be. The longer the focal length, the narrower the angle of view and the higher the magnification. The shorter the focal length, the wider the angle of view and the lower the magnification [Inc16] [Mam09]. Lowering the focal length gave the scene a large-scale feeling that was missing from the previous iteration.

The last change that was made was that the resolution was switched from 1920 x 1080 HD to 1920 x 817 wide aspect ratio. In movies, one of the uses for wider aspect ratios are that it could be used for opening shots to convey the idea of where the story will unfold [Sul16] [Mam09]. Cinematographers usually categorize wide view angles a few different ways. For this shot in particular the layout attempted to mimic the staging camera angle. This camera angle is a special type of long shot borrowed from the experience of stage plays [Sul16]. For example, it might be a shot of an entire room, where subjects are visible in different areas of the room; on the left and right, in the foreground and background, on a staircase, up on a balcony, each perhaps engaged in different activities. The staging camera angle serves as a kind of collage of subjects, who are unified by their presence in the same location, somehow psychologically and emotionally connected to each other simply by the fact that they are in the same place, even though they might not appear to be interacting directly with each other [Sul16]. These simple changes to the camera placement and settings produced a very drastic improvement in the final image of the scene, which can be observed in the work in progress before and after shots in Figure 2.21.

The layout stage was also the place where the scene was assembled and the placement of objects was laid out. The carefully designed modular models gave the layout artist ample freedom to experiment with scene composition and variety. Even though only one shot was created, the modular



Figure 2.21: Layout Work In Progress Before and After

elements have the ability to create several shots with different arrangements of the same selection of models. Assembling the scenes layout in this file also meant that every stage of the pipeline after layout would be able to subscribe to a single layout environment file rather than having to re-subscribe to the hundreds of models and textures every time for each animation, lighting, and FX file, increasing productivity and pipeline efficiency drastically.

Using elements from preproduction, such as concept art and rough environment blocking to guide the set design, the assets were laid out in a way that served to guide the eye around the scene, directing attention to different elements and characters. In order to take extra care to not distract the viewer from important aspects of the scene, a diagram was created in Photoshop with quick paint overs of where to direct the viewers eye with shapes and silhouettes of models. A near final study of the shot's composition can be seen in Figure 2.22, where the parallel lines of the sidewalk and buildings guide the viewers eye down the street to the actions of the characters. The symmetry was broken up periodically throughout the scene by the angled destruction elements. The remaining military and war components of the scene were also positioned strategically in the foreground, midground, and background to divert the viewers gaze from the main perspective lines created by the buildings to small details that would not normally be noticed like building signs, news posters, and smaller scale detailed models that enhance the story. The barbed wire in particular served as a useful tool to force a left to right directional shift in a scene mainly dominated by a front to back viewing angle. With the barbed wires procedural design and incredible flexibility, iterating their positions was incredibly simple and quick.

For the far background of the shot the procedural buildings were strategically placed to prevent a band of blank sky. The procedural tools allowed for a variety of styles and shapes of buildings to be generated, and provided customization of roof slopes in order to fit the comments

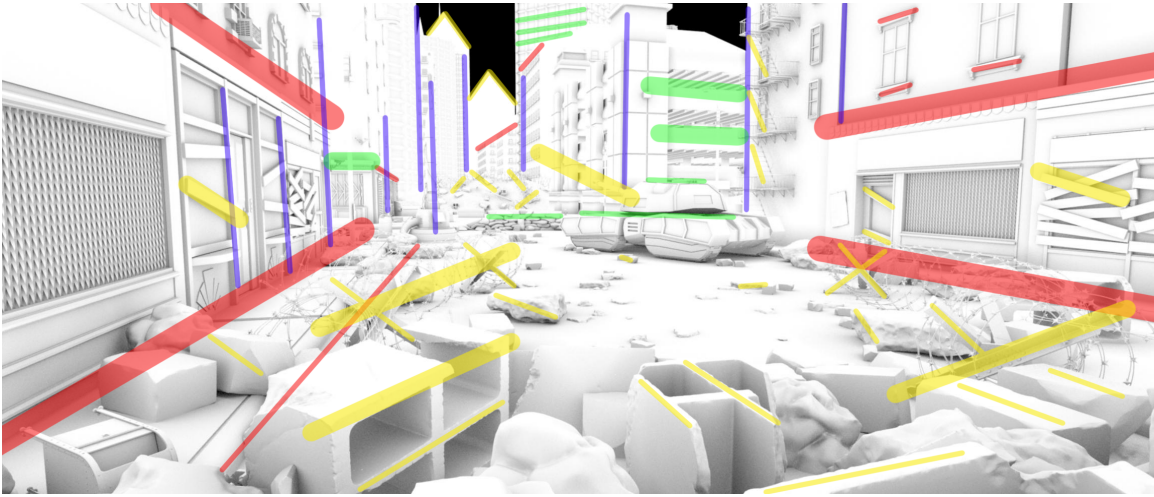


Figure 2.22: Layout Composition Diagram

from the layout artist.

In order to help the shot reach its goal of having a grand and large scale city, the artist manipulated the scale of some models in order to give a sense of forced perspective. Forced perspective is a technique, employing optical illusion to make an object appear farther away, closer, larger or smaller than it actually is [Dic16]. One good example of this technique can be seen in all of Peter Jackson's Lord of the Rings films. Characters standing next to each other in a scene, were displaced by several feet in depth from the camera. This, in a still shot, made some characters appear much smaller, especially for the dwarves and Hobbits, in relation to others [Jac01] and can be seen in Figure 2.23. For this project's layout in particular, objects in the foreground were scaled up slightly, specifically, the rocks and cinderblocks in the debris pile and the blue mailbox. In some animation tests the character appearing in the foreground was also scaled up as well. The procedural background buildings were also scaled down the farther back they went. The effect of widening objects in the foreground and when compared to the background created a sense of increased depth to the scene.

Combining the artistic tricks when assembling the scene and taking the time to research proper camera options as well as iterating on camera placement helped increase the effectiveness of the shot and caused a significant improvement to the visual quality of the rendered image. The time spent planning the overall composition, ensured that the final layout would hold up a high level of artistic and visual quality.



Figure 2.23: Lord of the Rings Forced Perspective Example [Jac01]

2.7 Animation

The animation stage of pipeline is the area where motion is given to a character. For this project animation was given to 2 robot characters in the scene. One robot who was stationed at the terminal, messing with the controls, and the other character was patrolling the street with his assault rifle. A careful balance was needed in order to give the robots human like traits but still resemble robots.

In order to help reinforce the fact that the characters are mainly machines, the character's were given sharp and direct movement to their hands and head. This gave the robot at the terminal a mechanical snap when pressing controls. The assumption was also made that the robot's vision was fixed like an owl and in order to look around the head needed to pivot at the neck. Adding the short and snappy movements gave the character's head a very robotic and engineered look.

In an attempt to give a little human movement to the character some of the sharp direct movements were offset by a few keyframes allowing the animation to have a blend of smoother motion and sharp quick movement. This allowed the animation to reach an interesting balance between human motion and machine.

2.8 Lighting

Lighting is the stage of the production pipeline where all of the assets come together and light is added to the scene. It is the first time in the production that the final image can be seen in its entirety. While the details of the lighting decisions for this production will be fleshed out in the later section, it is important to explain the basics of the lighting stage in broader details and why it is important.

Lighting is a key step in the process for making a scene come to life, and it is more than just adding some lights to a scene in Maya, hitting the render button, and calling it a day. Without light, a scene would lack motivation and story. For example, animation follows after establishing the character's purpose and goals [Bir14]. The same motivational analysis applies for lighting. The first step in lighting is always to think about what motivates the light in the scene and gather reference images. Reference can come from digital sources or are taken from everyday life. Typically, it is a good idea for lighting artists to keep a lighting journal or photography collection up to date with a variety of reference images taken from real life experiences. Artists can also utilize tonal studies and lighting paint overs in order to efficiently brainstorm and iterate on ideas as well as receive feedback quickly without having to waste time struggling with 3D tools.

Lighting has the power to influence the viewer's experience of a scene. By artistically controlling the time of day, colors in the scene, shadow patterns, and even the timing of changes in the light, a lighting artist can compel the viewer to feel different emotions, and imagine elements that do not exist off screen or out of frame. Lighting also can be used as an artistic story element. By graphing the story arc and mapping color keys to the different story beats, the artist can use changes in lighting to further reinforce the tone and mood of the story [Bir14]. For example, in the movie *Kung Fu Panda*, the main antagonist Tai Lung escapes a maximum-security prison. The lighting at the beginning of the sequence starts off dark and cool blue, but as the shots progress, the lighting gradually shifts from cool to warm. In the end, Tai Lung completes his escape and the shots are bathed in ominous red light. This transition can be seen in Figure 2.24 [DP08].

Lighting also has the ability to enhance the details of all elements in a scene from models and surfaces to animation and FX. If the lighting is bad then it can make a good model look terrible, but if the lighting is done right then it can help enhance the topology and draw attention to details that would otherwise be overlooked. An example of this can be seen in Figure 2.25 where the left

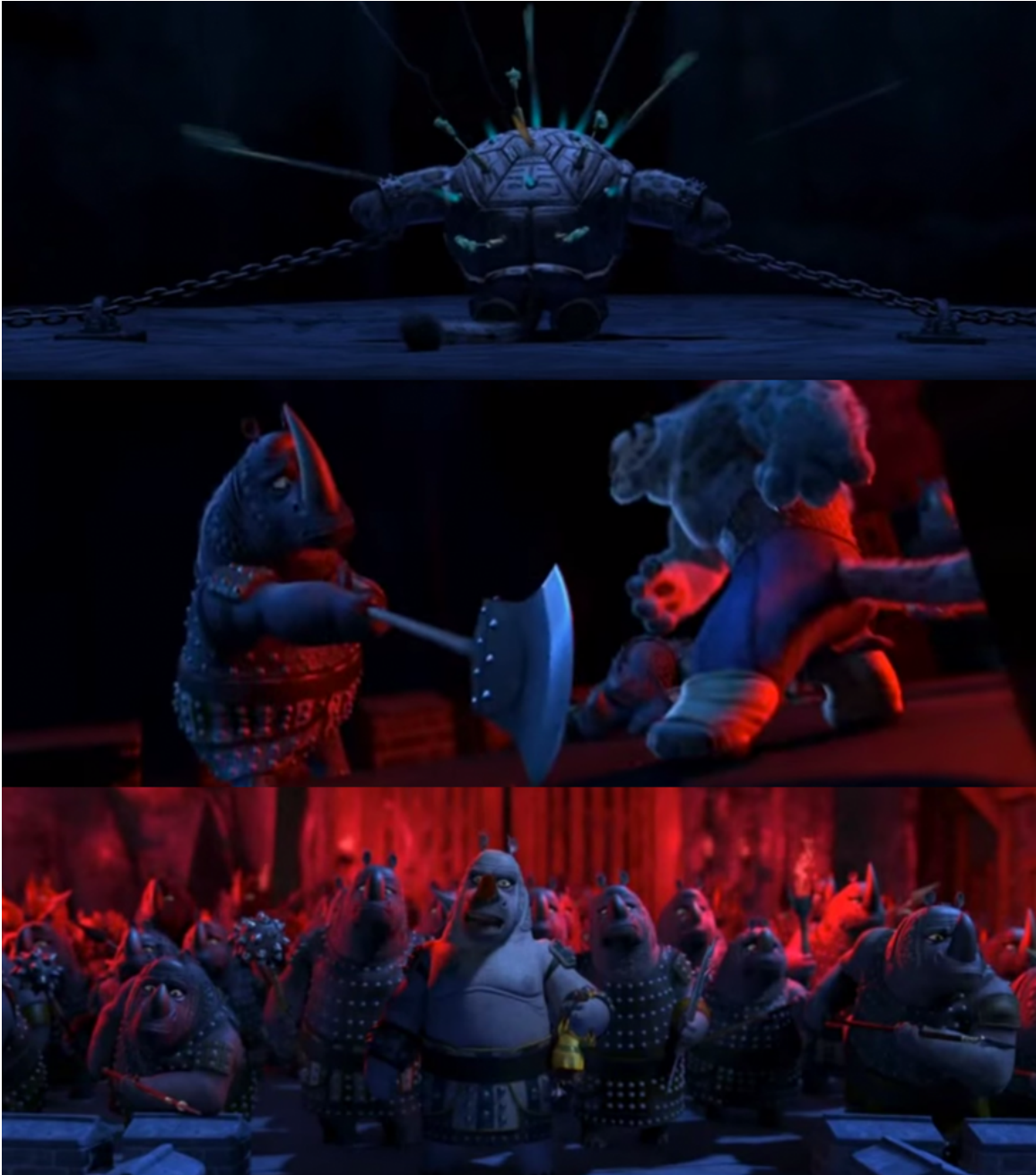


Figure 2.24: Tai Lung's Escape Lighting Transition [DP08]

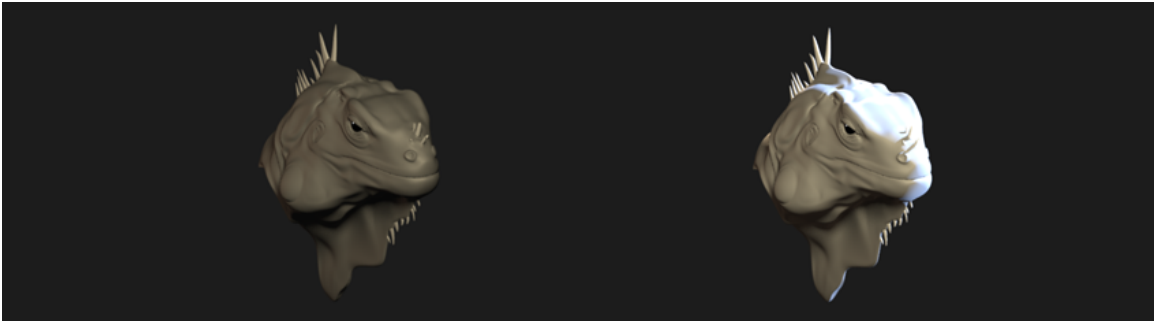


Figure 2.25: Painting with Light on a Basic Model

Iguana head has lost its volume and looks flat. The lighting on the right however, helps to accent the curves of the surface and to reveal the complex and well crafted structure of the model [Bir14].

2.9 FX

For this production, the FX department developed assets that could be tweaked later in the production. The FX department was also in charge of prototyping and creating dust, smoke, explosion, and other destruction elements that would be needed for other aspects of the story.

The FX stage permeated through several different departments in the animation pipeline. As mentioned in the modeling and layout sections, FX artists were able to create procedural buildings and barbed wire. Armed with the industry standard FX software, Houdini, artists created complex node based networks that generated the desired assets and supported a huge array of customization features. These assets were flexible enough to meet the layout artists demands and could be iterated on quickly and easily. For example the background buildings were so customizable that the modeling artist could provide a flat polygon in the shape they wished the base of the building to form and the tool was able to automatically produce the desired building in seconds. With optional controls to specify floor number, height, window count, window sizes, and roof styles, the FX artist could create an infinite number of arrangements for the modeling and layout department to choose from.

Another FX element was the smoke slowly rolling left to right in the shot. This added a layer of depth and atmosphere to the scene, and helped to sell the destruction in the warzone to the viewer. The smoke was layered in 3 sections: one for the foreground, midground, and background. Rendering out each of these in separate sections with RGB lighting pictured in Figure 2.26 allowed



Figure 2.26: RGB Smoke FX Render

the compositing artist to dial in the intensity of the smoke and color correct it so that it fit better in the plate and was less distracting. Separating the simulations into sections also decreased the complexity of the Houdini node network and optimized simulation and render times. Other elements of the story were also prototyped, i.e. the destruction of the parking deck and the explosion from the tank shell, Figure 2.27. This groundwork could help integrate these FX elements into additional shots.

In the end, the FX department played a major role in the success of the project and allowed the artists to iterate quicker and produce a better quality result. By planning and recognizing potential technical stumbling blocks early on, the FX team was able to discover and create new and intuitive solutions for production problems.

2.10 Compositing

Compositing is one of the last stages in the production pipeline. By taking the renders from lighting and FX, compositing artist are able to assemble the different elements of a shot into a final image. In most cases, the lighting artist sets the renders up with specific render passe's or AOVs to be used by the compositing artist. AOVs stand for Arbitrary Output Variables, and they provide a way of rendering any arbitrary shading network component into different images, or for this project, into a single EXR image [Ang16a]. An example of some rendered AOVs can be seen in Figure 2.28

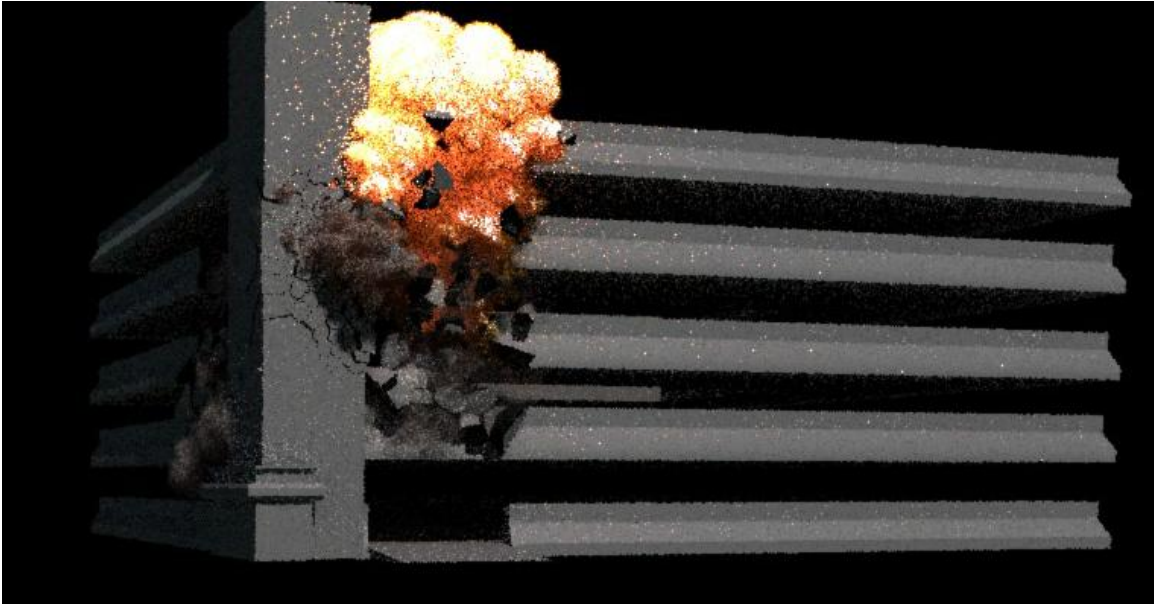


Figure 2.27: Explosion And Destruction FX Prototype

[Ang16a]. By separating different aspects of the image out into layers, the compositing artist has the power to heavily control the final image.

For compositing on this project the team used Nuke, a tool that has been well established in the Clemson Digital Production Arts pipeline and was used on several past projects at Clemson. The main benefit to using Nuke was the fact that it has an intuitive node-based workflow, making it very easy to create and debug different aspects of a shot. An example node tree for this project can be seen in Figure 2.29. Isolating different areas like the background from the foreground and applying color correction to specific pieces is quick and easy to implement. If something goes wrong in the composite, the workflow for correcting the problem is quick and efficient. By systematically checking the image as it progresses down the node tree, the compositor would eventually narrow down the problem and isolate what went wrong.

But solving compositing tree errors were not the only challenges that had to be tackled. By integrating Arnold into the production pipeline, optimal render settings and Arnold lighting best practices needed to be relearned in order to maximize image quality without wasting computing power and rendering time. This meant that the compositing artist needed to work closely with the lighting department in order to make sure problems were solved and that the whole render process was optimized. For this project it was decided that the lighting artist would also be the compositing

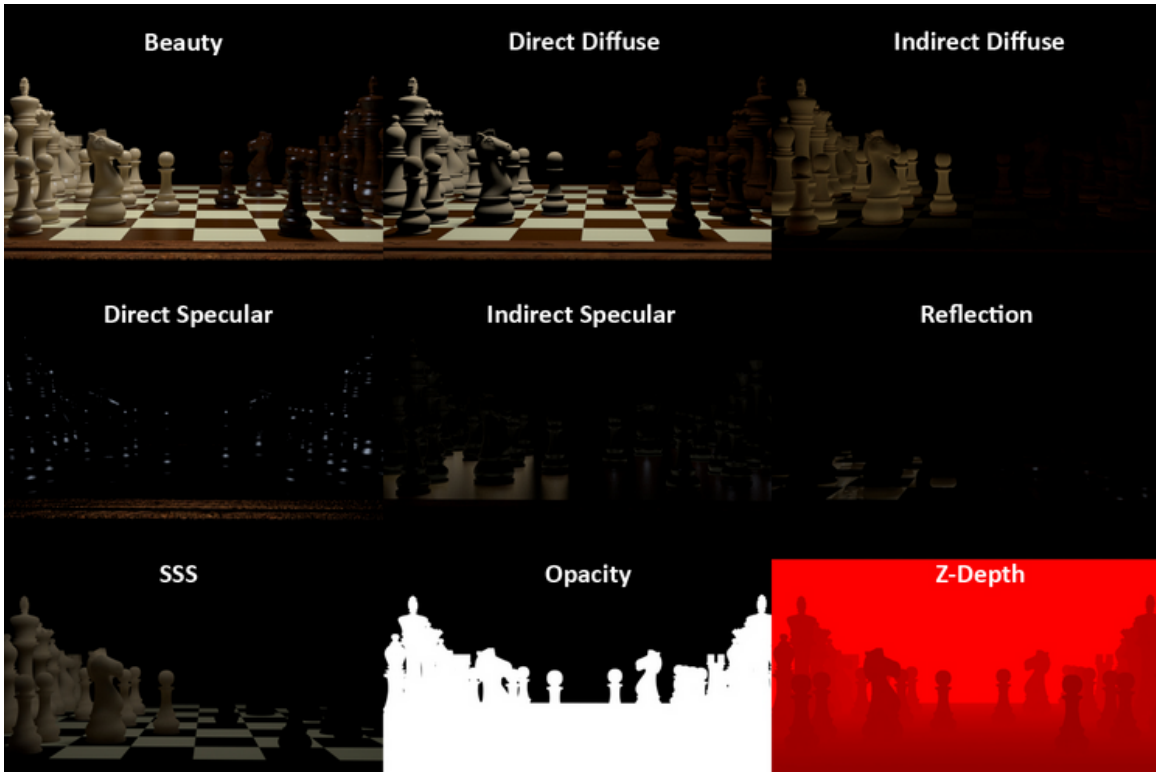


Figure 2.28: Example Arnold AOV's [Ang16a]

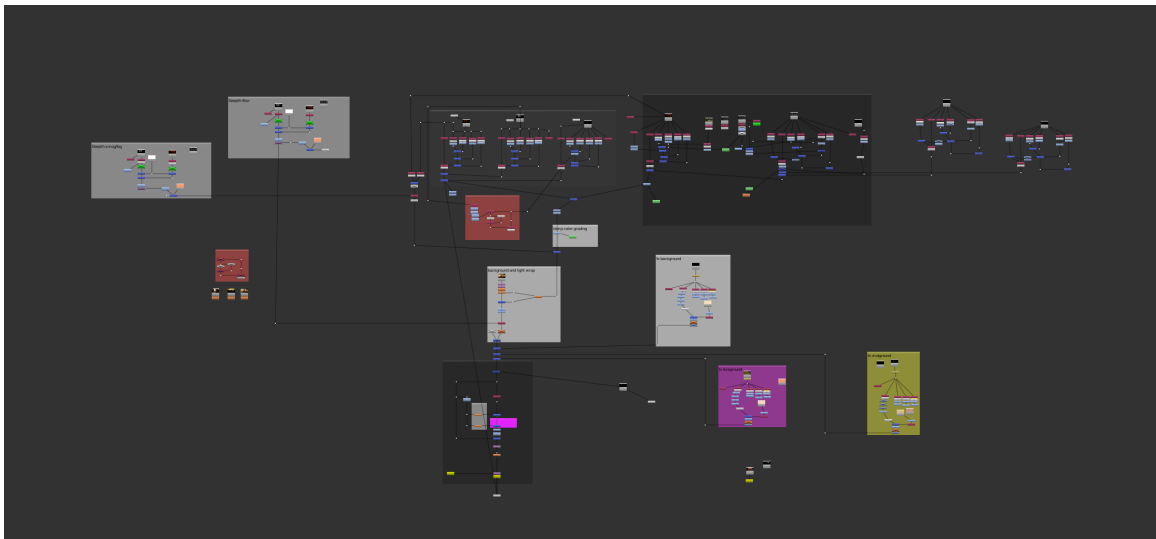


Figure 2.29: Nuke Node Tree For This Project

artist because there was only one shot, and it prevented communication issues between departments.

When rendering the render layers from lighting for the whole frame range, the sequence of images produced a lot of visible noise and rendering artifacts. The noise occurred in areas of indirect shadow as well as in the specular highlights of the scene. In addition, there were single pixel flickers of very bright color values that would pop in on single frames and occur randomly throughout the sequence. This was due to the use of a third party shader, which were used on certain objects in the scene combined with standard Arnold shaders. In order to tackle the artifacting problem, a series of steps were taken in conjunction with the lighting and compositing departments. The first step was to increase the number of light samples as well as the diffuse and specular Anti Alias samples in the render settings. In Arnold, sampling is the generalized setting that can be controlled to increase the overall image quality of a render. For example, controlling the number of diffuse samples controls the number of rays fired when computing the reflected indirect- radiance integrated over the hemisphere. The exact number of hemispherical rays is the square of the diffuse sample value, so increasing that number reduced the indirect noise [Ang16d]. It is important to note that sampling is done for each Anti Alias ray meaning that high values of Anti Alias samples and diffuse or specular samples resulted in extremely long render times. Anti Alias samples were mainly used as a global quality control for the scene [Ang16d]. It was found that increasing Anti Alias samples to no more than 12 drastically reduced the amount of rendering noise artifacts without increasing render times drastically. Unfortunately, increasing samples did not correct the firefly artifacts. Instead a backup plan was created.

In order to correct the artifacts, since the camera was stationary in the scene, it was sufficient to render a single frame for the environment, which would show zero noise artifacting. Objects in motion, like characters, were already rendered separately because they required special lighting treatment and would be integrated into the single frame with a mixture of masking tricks and rotoscope nodes to isolate the moving from the non-moving portions of the scene. This allowed the final product to become noise free with minimal effort. The decision also optimized render time and meant that the number of frames that needed to be rendered went from 400 frames at approximately 20 minutes a frame to 1 single frame.

Chapter 3

Scene Lighting

The lighting for this project went through several stages. In order to achieve a high quality result the lighting had to plan out for the shot through the use of proper tools and techniques. In order to achieve the desired result, the lighting needed to ensure that all elements were used properly to form a composition that was cohesive and visually appealing. The lighting artist also had to tackle the challenge of working with the new renderer Arnold and become willing to throw away old workflows and flexible enough to adapt to new lighting techniques in order to achieve the best result.

The first step in lighting was to establish the motivation for the lighting in the scene and gather reference images. In the story the city was in ruin. Debris and destruction strewn around the street, and an eerie silence has set in. The lighting was intended to give the feeling of tension to an otherwise calm shot. Sunset was pitched as the time of day as it would allow for the range of colors to be more aggressive and energetic and create interesting shadow patterns from the lower angles coming from the sun. A series of reference images were found that would serve to guide the lighting design. These reference images, seen in Figure 3.1, depict buildings at various scales and how the sunset affects the lighting and shadows of the scene [Gui10] [Bak16] [Kul12]. It was noted that the reference images did not let the shadows fall to pure black. By varying the shadows value, the features and details of the buildings were brought out and improved the overall composition of the image. The reference images also contained elements of atmospheric and natural looking glow that would also play a key roll in achieving a believable final product. Other elements such as shadow strength, color, and contrast were also examined and helped influence the final product.

In addition to reference images, the lighting artist rendered out an ambient occlusion render of the scene and painted a lighting tonal studies, serving as rough plans for light placement and intensity. This tonal study, pictured in Figure 3.2, helped the lighter brainstorm possible lighting scenarios for the shot quickly without having to struggle with the 3D software. The purpose of the tonal studies were to plan out a lighting composition that featured a balance of light and shadow and created an interesting composition with repeating patterns of light on dark. Once a design was settled upon the artist could use the paint overs as rough guidelines when laying out the lights in Maya.

After the planning stage, Maya lighting began. In order to create a desired result, The Arnold area light was chosen as the primary light type for the shot, because of its compatibility with Arnold shaders. It also prevented any problems with inconsistencies when trying to combine Maya lights and Arnold lights together. The Arnold area lights also supported features like color temperature, exposure, light shape, decay, and light blockers and gobos. The Arnold area light also had settings to mimic other types of lights including spotlights, and directional lights. This made it the natural choice for use in the scene. Additionally the Arnold environment sphere was used to provide realistic indirect and fill light for the scene, in conjunction with an HDRI image of a sunset pictured in Figure 3.3 [Van16a].

In order to create an interesting composition with light, a balance of light on dark was crafted in the shot. In order to enhance details in the scene, a pattern was created. A shadowed background accented objects bathed in sunlight in the foreground. Similarly a brighter background silhouetted objects in shadow. An example of this technique can be seen in Figure 3.4 where the tank alternates from shadow to light and the background is lit in order to draw attention to the tank's features. Using this technique created a interesting pattern of light on dark on light and helped the environment and characters stand out in the shot. It also helped define depth through light and shadow in the shot [Bir14].

In lighting, a common practice for setting up a scene is to break lights out into separate render layers in Maya [Bir14]. This technique is especially useful for working with and debugging lights. It is always recommended to work with one light at a time to make sure the lighting artist is intentionally positioning the light where they mean for it to go [Bir14]. The process of soloing a light serves to reduce complexity and allows the artist to narrow down the light contributions of a scene in order to solve difficult light and shadow problems when they arise. Rendering one light at a time also gives compositing artists a lot of control over the lighting in post. However, breaking

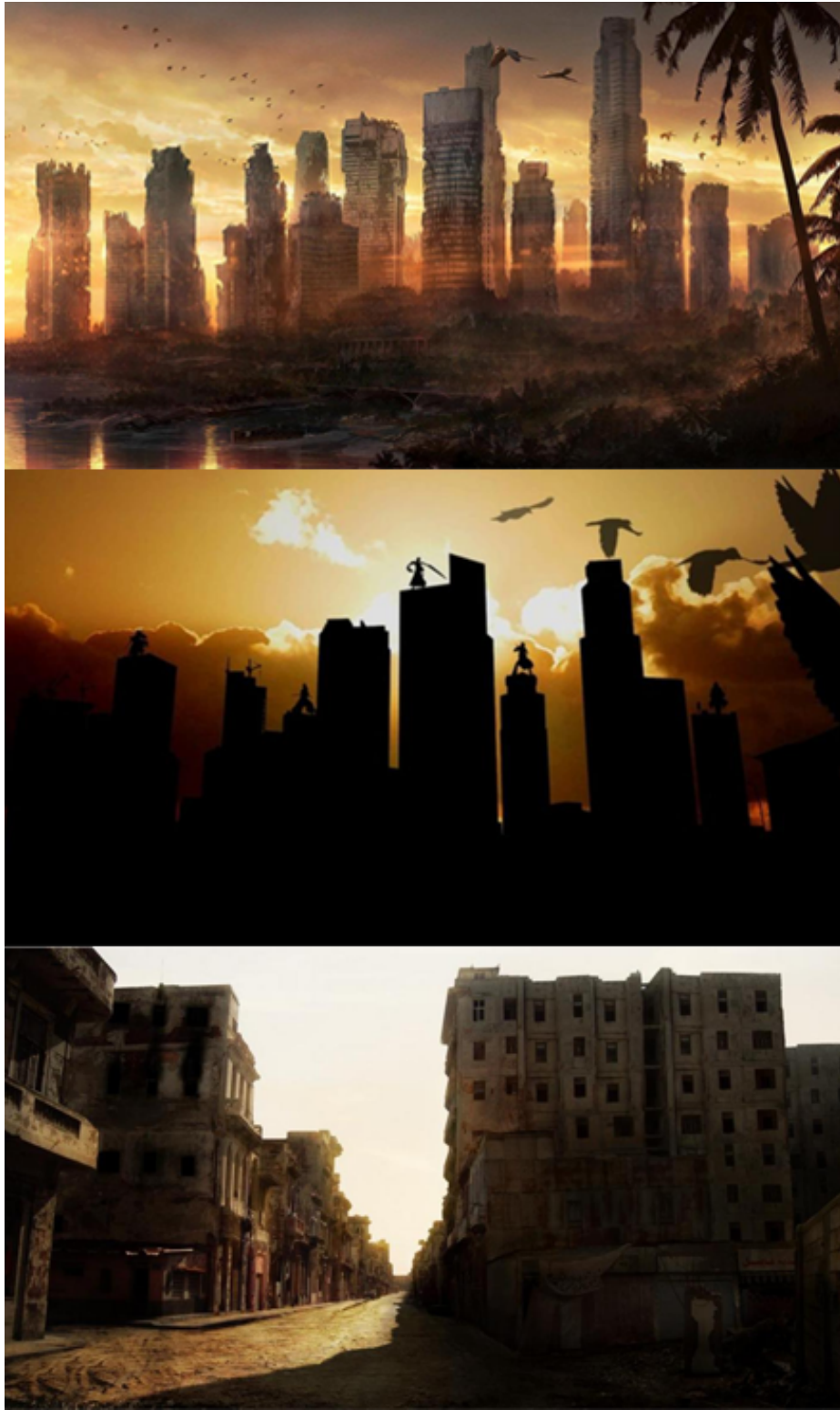


Figure 3.1: Lighting Reference Images [Gui10] [Bak16] [Kul12]

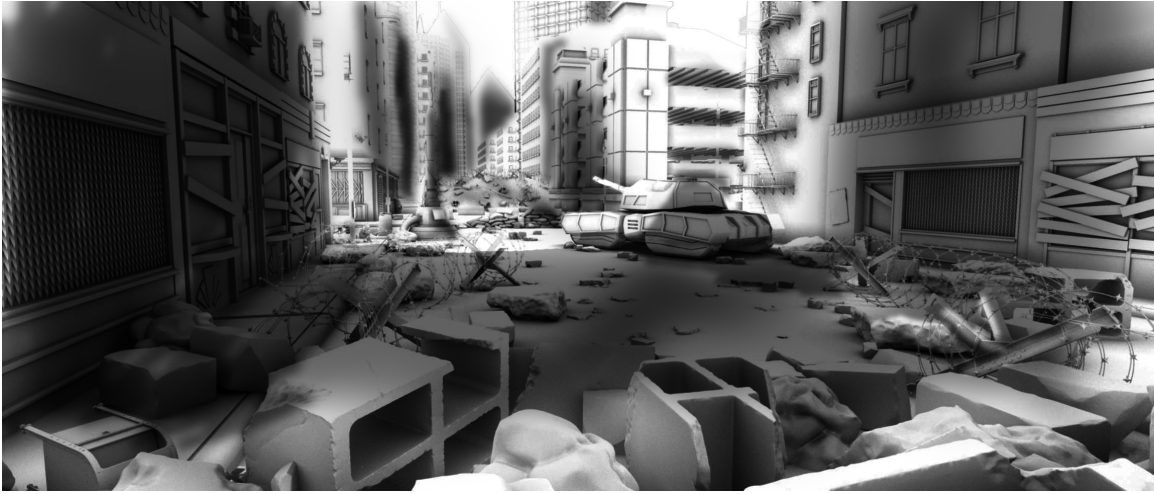


Figure 3.2: Lighting Tonal Studies



Figure 3.3: HDRI Image [Van16a]



Figure 3.4: Alternating Light on Dark with the Tank

out every light into separate render layers does have several downsides. Depending on the scene, the artist might inadvertently overcomplicate the setup in their attempt to maintain control, putting a burden on the compositing artist. The image also loses natural light, color, and shadow blending that would normally occur when the lights are rendered together. In order to have the useful control of separated lighting but not lose the natural look and ease of use of a scene, the lighting artist chose to keep the environment together as much as possible, in each render layer. Only the background buildings were separated from the rest of the environment due to the fact that their lighting was slightly altered for artistic purposes. For the majority of the set, the main lighting layers used were the key and fill layers. The key light was given a color temperature between 100K and 400K, pictured in Figure 3.5 which gave the key a value of color that fell in a typical sunset range [Ang16b]. The fill light was a combination of the environment sphere and a few area lights. The fill area lights were assigned a purple or blue color value in order to represent bounce light from the blue sky during the afternoon.

Character lighting was addressed separately from the rest of the environment. In order to support the characters in the scene, a separate light rig was created. By parenting an adjustable key light to the character and breaking the characters key and fill lights into separate render layers, the lighter and compositor had the power to control light in order to help accent the characters

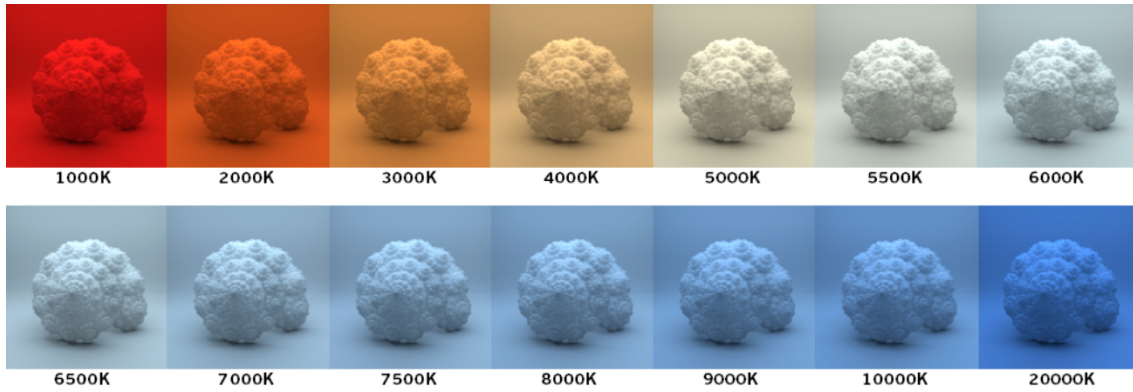


Figure 3.5: Color Temperature Diagram [Ang16b]

features independently from the environment lighting. Without this the scene looks muddy and the characters blended in a bit more with the environment. It was also important to avoid drastically breaking away from the environment's lighting due to the risk of making the character look out of place from the rest of the scene. By matching color and intensities of key and fill lights as well as testing with the actual lights from the environment, a good balance was achieved between character and environment lighting.

One aspect of the shot that needed to be addressed was the topic of atmospherics. Atmospherics plays a roll in many scenes, tinting and changing the appearance of more distant objects [Bir14]. In the war torn city, dust and debris provided the perfect motivation for adding atmospherics. The use of atmospherics can be seen in the film Spiderman 2 pictured in Figure 3.6 [SS04]. Using the depth map produced from the Arnold render, a layer of fog tinted by the color of the key light was created and is pictured in Figure 3.7. Using the depth map gave the compositor options to tune the thickness of the fog in post, as well as control where it appeared in the scene. Lightly adding in the fog created atmospheric perspective and a sense of smog that did not exist prior, and can be seen in Figure 3.8. Additionally the dust and smoke FX also helped add variation to the lighting in the foreground and mid-ground of the scene.



Figure 3.6: Spiderman 2 Atmospherics [SS04]



Figure 3.7: Fog Created by the Depth Map

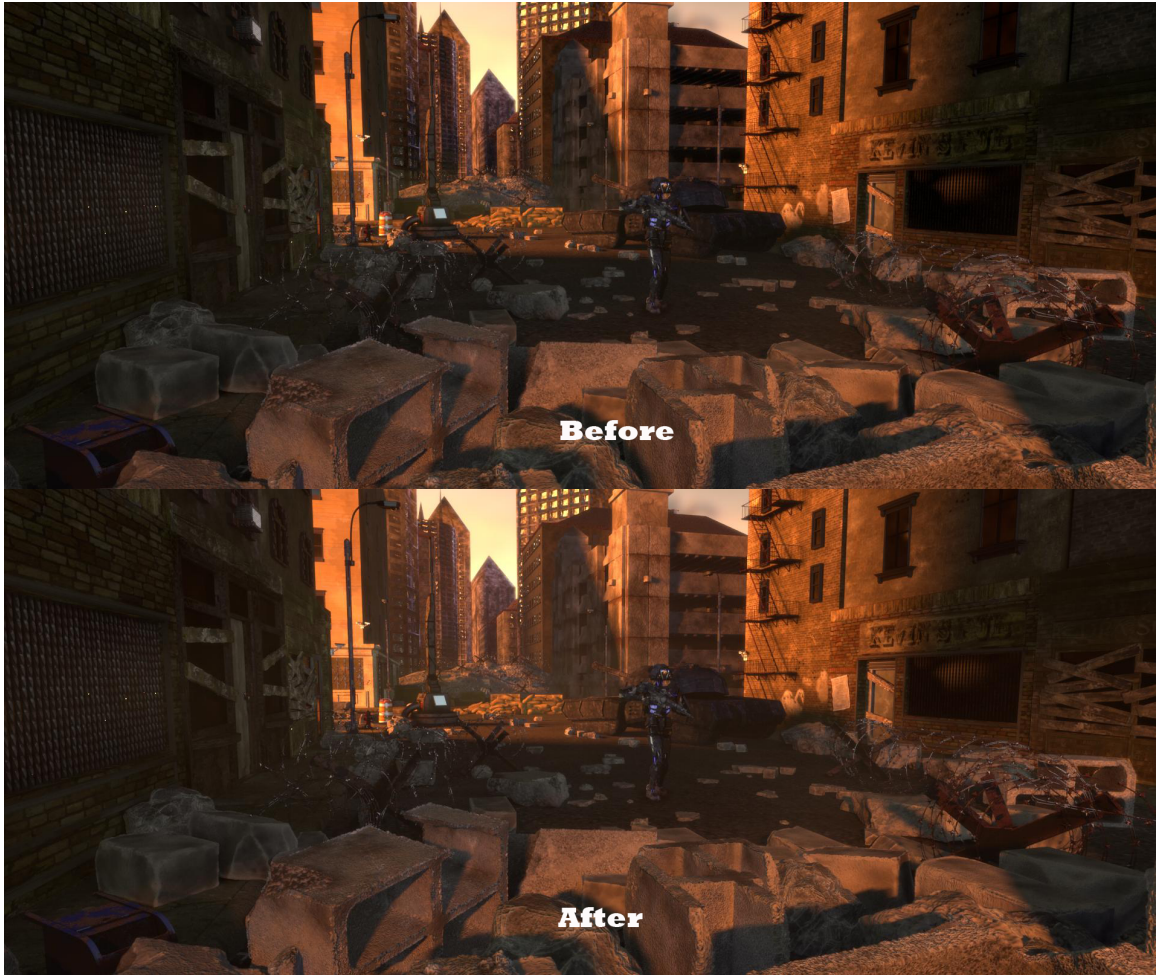


Figure 3.8: Atmospherics Added to the Scene Before and After

Chapter 4

Results

A large amount of time devoted to asset creation produced a collection of detailed 3D models that accurately matched their real world counterparts. A selection of these can be seen in Figure 4.1 which compares several small-scale environment models with their photo references collected in the preproduction stage. The small details captured in the model helped the believability of the scene and served to decrease the amount of surfacing detail needed for each object.

Taking the time to iterate on hand painted maps for larger scale models in surfacing resulted in organic and natural looking textures. The decay, destruction, bullet holes, and rusted windows in the building facade textures pictured in Figure 4.2 helped give the city an abandoned and desolate feeling. The combination of hand painted textures and procedural shaders transformed the environment into a post apocalyptic warzone.

The completed establishing shot is pictured in Figure 4.3. The final render consists of 400 frames, featuring a destroyed city, tank, and robots patrolling the streets. Special care was taken in designing the layout of the shot in order to create an interesting and appealing composition. Patterns in light, shadow, and atmospherics create a sense of depth and help accent silhouettes of characters and objects.

Everything in the final product was rendered using Arnold; apart from the Houdini smoke FX. New workflows were discovered, new software was used, documentation was created, and existing tools were adapted in order to integrate Arnold renderer into the Clemson Digital production Arts animation pipeline. The result of these changes meant that Arnold has become a viable option for future animation projects. Its speed, efficiency, and ease of use provides an excellent alternative to



Figure 4.1: Models Compared to Reference Images



Figure 4.2: Facade Textures



Figure 4.3: Final Scene

Renderman and Mental Ray.

Chapter 5

Conclusions and Discussion

The structure of this animated short was designed with a similar process to past productions at Clemson University DPA program, and the theme of efficiency and optimization was stressed in every stage of the project. New software was used in order to increase artist productivity. Asset generation was planned out in advance in order to maximize variation, reusability, and visual quality of the final product. Detailed models and textures were created in order to achieve the visual goal laid out by story, and match the style designed in the preproduction stage. Additionally, by continuously iterating on the artistic elements of the shot including: modeling, surfacing, lighting, and layout, the artists were able to improve the aesthetic and composition of the project. By using Arnold for shading, lighting, and rendering, final frames were produced quickly, and making corrections to image quality and noise artifacts were relatively painless when compared to other renderers used for past projects.

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