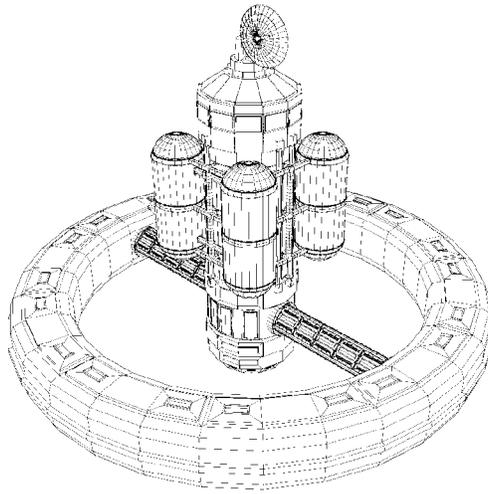


The Station Keeper

By Peyton VanHook



Documentation for
BFA Animation Thesis Project

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Artist Bio:

Peyton VanHook is a current undergraduate student at Austin Peay State University with a Bachelors Degree in Animation + Visual Effects and Computer Science + Information Systems. They are well versed in programs such as: Autodesk Maya, Blender, Adobe Suite, Toonboom Harmony, and Nuke.

Peyton is a Jackson Alley Film Festival award winning co-director, co-editor, co-writer, and animator who has been accepted into the 2019 and 2020 SIGGRAPH Conventions in the Faculty Submitted Student Showcase. They have competed and represented Austin Peay State University in the 2017, 2018, and 2019 24 Hours Animation Competition.

Abstract:

Through this project I will explore the full process of making a 3D short animated film, which utilizes an original story. In my story, I explore the fear of isolation and change inherent in major life transitions, and the importance of being open to change rather than stuck in nostalgia. I'm exploring these themes using the lens of science fiction, and I'm utilizing non-verbal and environmental storytelling techniques to build a world which helps communicate the themes of the story.

Summary:

I am drawn to animation for a number of reasons. First, infinite nuance and fractal-like detail exists in how creatures and people move and behave. Animation is, in part, about capturing this detail and distilling it to create compelling movement and, by extension, develop compelling characters. I am fascinated by this process and how, when properly utilized, it can breathe life into even the simplest characters. Second, I am fascinated by non-verbal storytelling, i.e. creating a story from character expression, movement, and environmental storytelling rather than dialogue. Much of my work to-date has been pantomime and non-verbal, so I want to continue exploring that in my senior thesis.

My goals with this project is to expand and refine my knowledge in independent story development for animation, and to learn character animation. In my classes I have not been able to cover character animation, especially character facial animation, extensively, so I want to pursue this topic independently. Additionally, I've had several experiences working with a team to develop short animated films, but I would like to learn how to develop a project with a more reasonable length of development time. Additionally, I want to work through each stage of the animation pipeline, so I can be more aware and understanding of the entire film development process once I begin my career in the industry.

Resume:

Peyton VanHook

Environment Designer, Animator, VFX Artist

phone:

email:

website:

instagram:

423 693 9244

pvanhook208@gmail.com

tinyurl.com/peyton-of-the-arts

peyton.of.the.arts

Software Experience

Maya
Blender
Toonboom
After Effects
Premier Pro
Nuke
Photoshop
Indesign
Illustrator
Renderman

Notable Skills

Hard-edge Modeling	Procedural Shading
Node-based Comp.	MEL Scripting
Soft-edge Modeling	Motion Tracking
Fluid & Physics Sims.	Pipeline Development
Cloth & Soft-body Sims.	Project Management
Rigging	Technical Support
UV Mapping	Compiler Design
Texturing & Digital Painting	Website Design in HTML

Proficient Languages

C++
C#
Java
Python
Haskell
PHP
mySQL
Javascript
Prolog
OSL

Education

Bachelor of Fine Arts, majored in Animation + Visual Effects

Graduated in December 2020

Austin Peay State University, Clarksville TN

- APSU Center for the Creative Arts Performance Scholarship: 2016 - 2019
- APSU Presidential Scholarship: 2015 - 2019

Bachelor of Science, majored in Computer Theory & Systems

Graduated in December 2020

Austin Peay State University, Clarksville TN

- Ken & Amy Landrum Computer Science & Info. Technology Scholarship: 2017 - 2019

Experience

Inventory Manager of APSU Art + Design's Equipment Checkout Service

August 2017 — December 2020

- Developed custom inventory management software.
- Maintained inventory of 200 items, including cameras, drawing tablets, etc.
- Provided technical support for students & faculty who checked out items.
- Provided technical support for faculty on Department computers & printers.

Recognition

9th Annual Faculty Submitted Student Work Exhibition

SIGGRAPH 2020

- Motion Tracking & Compositing shot
- Part of a collaborative 'trailer' project with students from APSU Anim & VFX.

8th Annual Faculty Submitted Student Work Exhibition

SIGGRAPH 2019

- 2 Shots featured in student work exhibition.
- Green screen miniature shot, featuring compositing, tracking, and CG shadows.
- Animated Camera sequence featuring posed still characters in an action sequence.

The Pitch — 'Best in Fest' at APSU's 2nd Annual Jackson Alley Film Festival

April 2019

- Director of 3 minute animated short produced by myself and 3 classmates.
- Created and maintained project pipeline.
- Also modeled & textured the set, animated the camera in all shots.
- First animated short submitted to the festival.

Competed in International 24 Hours Competition

October 2017, 2018, 2019

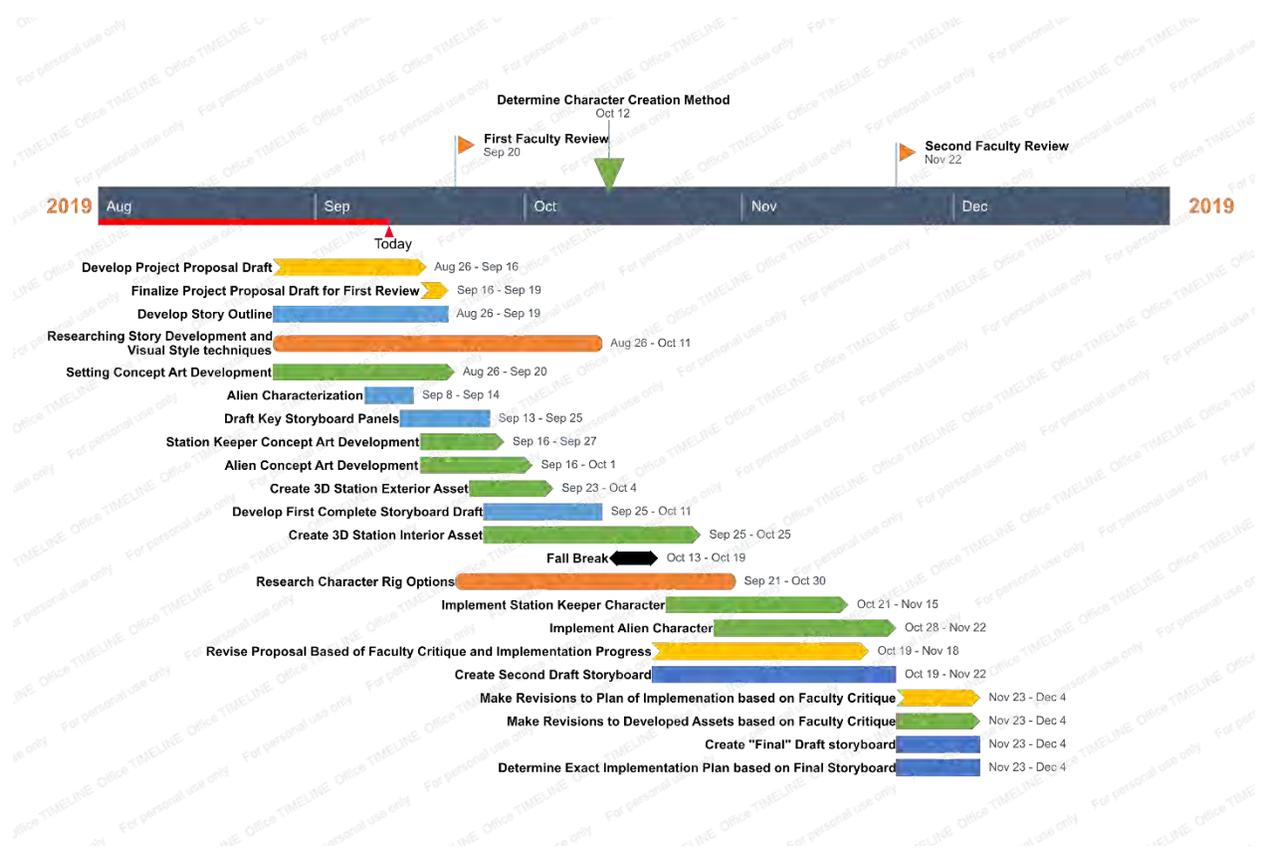
- Created a 30 second animated short from scratch within 24 hours with a team of five.

Methodology:

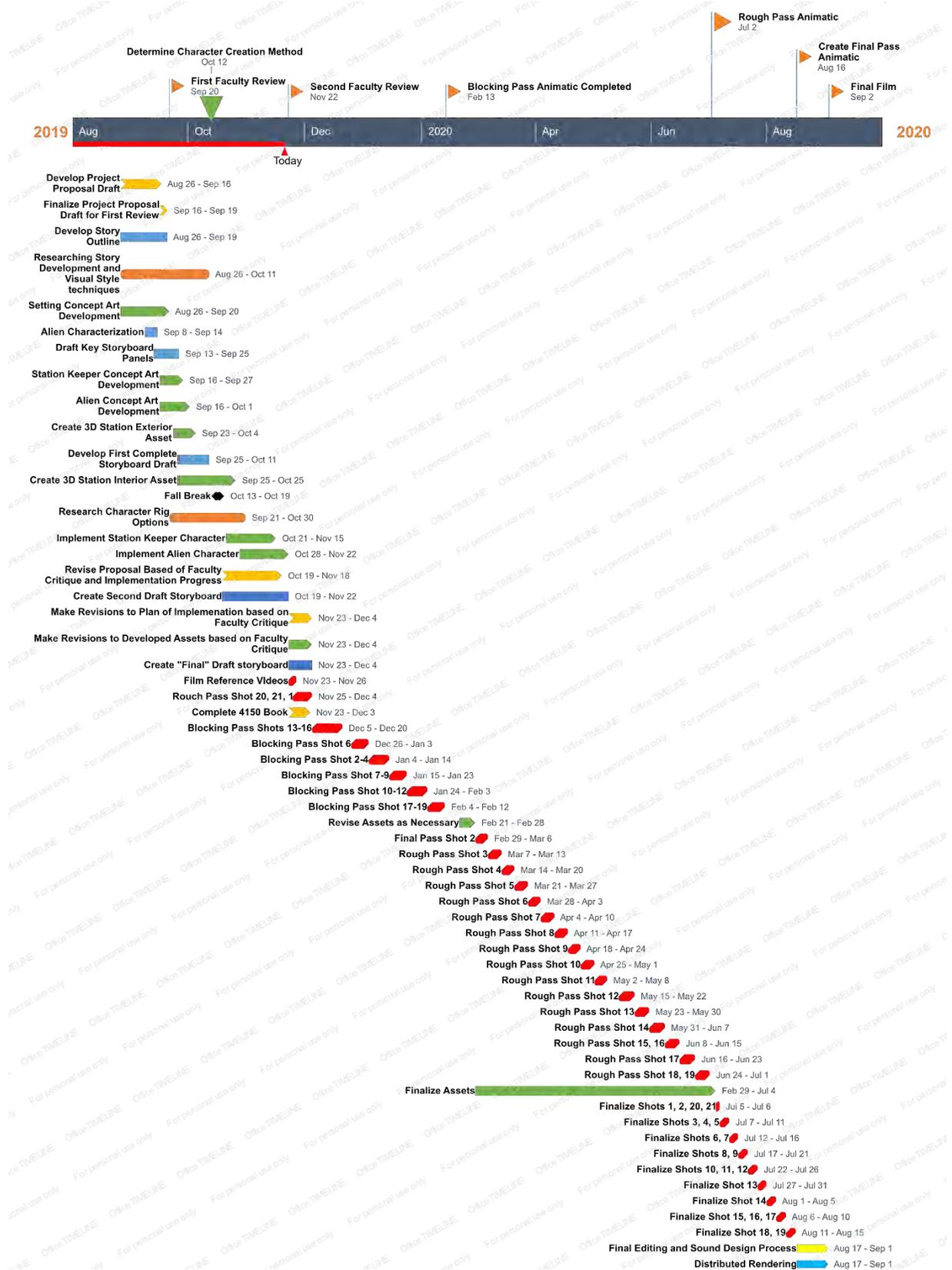
During the course of this project, I will be utilizing the following techniques:

- Story Development
 - o Outlining independently created story
 - o Develop into storyboard for animation
- Storyboarding
 - o Illustration
- 3D Modeling
 - o Character Models
 - o Setting Models
 - o Prop Models
- Character Rigging
 - o Adapted from source
- Art Style Development
 - o Develop cohesive visual style that serves the story
- 3D Character Animation
 - o Character Movement
 - o Character Expression
 - o Character Interaction
- Cinematography
 - o Communicating story beats and emotion through non-verbal means
 - o Establishing world through peripheral environment
 - o Determining order and length of sequences needed
- Compositing
 - o Utilizing visual effects and compositing techniques to establish story elements
- Editing
 - o Compiling composited shots into final sequence with music, sound effects, etc.

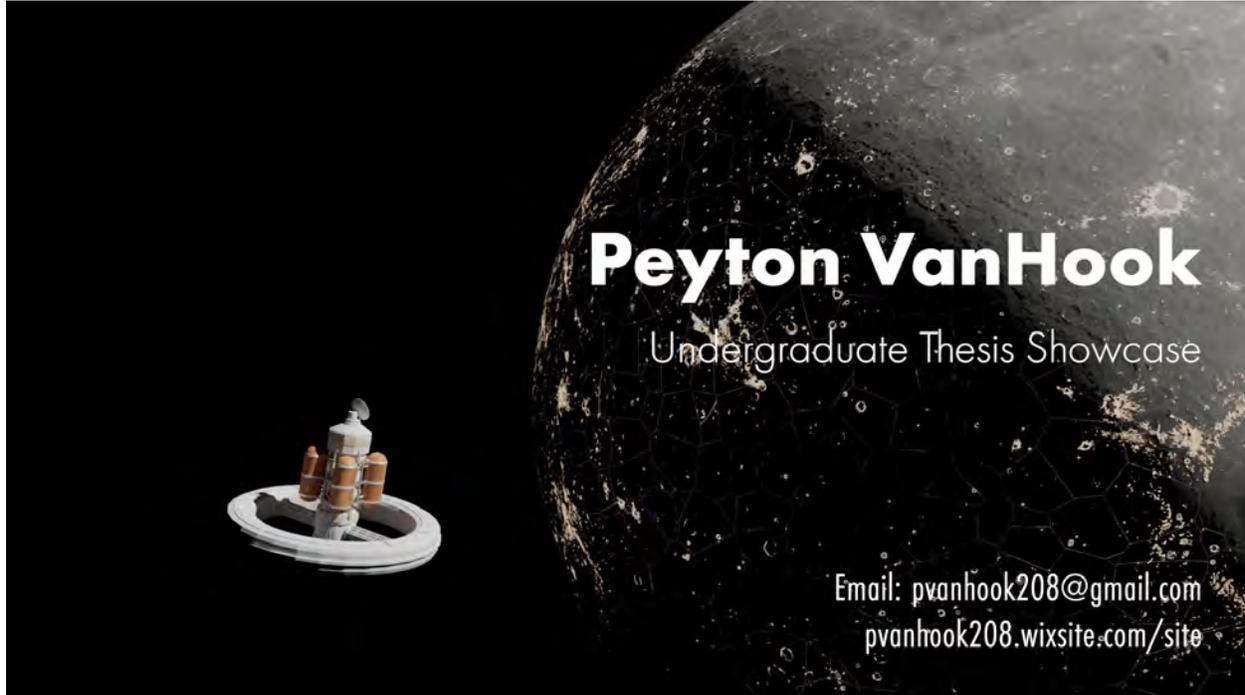
Fall 2019 Gantt Chart



Fall 2019 -> Fall 2020 Gantt Chart



Demo Reel:



<https://youtu.be/ciGLpsMb86E>

Breakdown:

Title Shot: Animation, surfacing, modeling, and rigging of space station exterior; surfacing of the Moon.

(0:12 - 0:16) : Modeling & Surfacing of space station exterior

(0:16 - 0:21) : Modeling & Surfacing of space station exterior and interior, with the habitat ring removed to demonstrate how the interior fits in the space station model.

(0:21 - 0:37): Modeling & Surfacing of the space station interior, demonstrating the curvature of the interior set.

(0:37 - 0:52): Same as the previous shot, but viewed from the opposite direction.

(0:52 - 1:00): Turnaround of the computer console object which appears in the “command room” of the space station. Features modeling & surfacing work.

(1:00 - 1:06): Demonstrates a expression which introduces distortion to the images displayed on the computer monitors based on the position of a simple rig, which is not visible. This is one of two Python expressions utilized in this version of the project.

(1:06 - 1:16): Breakdown of the command room, which shows a unsurfaced model pass, an ambient occlusion pass, a flat lighting pass, and a beauty lighting pass.

(1:16 - 1:24): One partially completed shot from the storyboard, which shows a unsurfaced pass of the character moving through the command room and fades to a fully lit pass, showing screen distortion and full lighting in the scene.

(1:24 - 1:32): A turnaround of a hallway featuring modeling and surfacing work.

(1:32 - 1:41): A breakdown shot showing the flat modeled pass, which fades to an ambient occlusion pass, which fades to a fully lit pass. This shot features the hallway segment in the previous shot made into a full curved hallway.

(1:41 - 1:46): A turnaround of a ‘tricorder,’ a prop from *Star Trek*. Showcasing modeling and surfacing work.

(1:46 - 1:57): The second expression driven shader featured in this project. A sequence of shader nodes are used to determine the image (in the case of the paper) or color (in the case of the book) which is used in the final render. This expression allows for random variation in props without significant work on the artist’s part.

(1:57 - 2:05): A turnaround shot featuring a number of props made for the living space, to add visual depth and visually portray the character’s disorganized personality and mental state. This showcases modeling and surfacing on a number of smaller props, and how the paper and book shader expressions allow for some visual variation in the scene.

(2:05 - 2:15): A breakdown shot showing the flat shaded pass, ambient occlusion, flat lit, and fully lit versions of the living room set.

(2:15 - 2:26): Closing shot, showing the space station exterior, the Moon, and the Earth. Showcasing modeling & shading work, textures on the Moon and Earth sourced from NASA.

Personal Website: <https://pvanhook208.wixsite.com/site>



Peyton VanHook
3D Environment Modeller, Animator, & VFX Artist



- Home
- New Work
- Bio & Contact
- Resume
- Blog

Demo Reel



Peyton VanHook
3D Environment Modeller, Animator, & VFX Artist



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About

Peyton VanHook

Peyton VanHook is a current undergraduate student at Austin Peay State University with a Bachelors Degree in Animation + Visual Effects and Computer Science + Information Systems. They are well versed in programs such as: Autodesk Maya, Blender, Adobe Suite, Toonboom Harmony, and Nuke.

Peyton is a Jackson Alley Film Festival award winning co-director, co-editor, co-writer, and animator who has been accepted into the 2019 Siggraph Convention. They have competed and represented Austin Peay State University in the 2017, 2018, and 2019 24 Hours Animation Competition.

Awards & Highlights

"Best in Fest"
Jackson Alley Film Festival, 2019

Faculty Submitted Student Panel
National SIGGRAPH Convention, 2019
National SIGGRAPH Convention, 2020

Placed Top 50
24 Hours Animation Competition, 2019



Peyton VanHook

3D Environment Modeller, Animator, & VFX Artist



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Resume

Peyton VanHook

Environment Designer, Animator, VFX Artist

phone: 423 693 9244
 email: pvanhook208@gmail.com
 website: tinyurl.com/peyton-of-the-arts
 instagram: peyton.of.the.arts

Software Experience	Notable Skills		Proficient Languages
Maya Blender Toonboom After Effects Premier Pro Nuke Photoshop Indesign Illustrator Renderman	Hard-edge Modeling Node-based Comp. Soft-edge Modeling Fluid & Physics Sims. Cloth & Soft-body Sims. Rigging UV Mapping Texturing & Digital Painting	Procedural Shading MEL Scripting Motion Tracking Pipeline Development Project Management Technical Support Compiler Design Website Design in HTML	C++ C# Java Python Haskell PHP MySQL Javascript Prolog OSL

Education Bachelor of Fine Arts, majored in Animation + Visual Effects

Narrative Research

In developing my story I take inspiration from the work of Pixar in their various short films and other pantomime sequences in their films. Namely, the prologue montage of "Up" and the first act of "WALL-E" are major influences for the kind of storytelling I look to utilize in this project. Furthermore, I've researched short films by other groups such as "Planet Unknown" by Shawn Wang, "The Present" by Jacob Frey, and others. These films all predominantly rely on non-verbal storytelling, instead focusing on character expression and movement to develop the story and the individual characters.

Additionally, I am inspired by Stanley Kubrick's *2001: a space odyssey*. In the film, Kubrick utilizes environmental and cinematographic techniques to tell the story, rather than relying exclusively on dialogue. Kubrick grounds the viewer first in the known, real world by introducing the viewer to familiar settings at the start of the film. The film begins on Earth, and then transitions to a space station branded with familiar corporate names (Pan-Am, AT&T, Hilton, etc.). But as the monolith is brought into focus the story begins to shift into the unknown vastness of space, and the complete isolation the characters experience serve to heighten the mystery and tension of the plot.

In my thesis, I am utilizing similar techniques to telegraph and display my character's emotions and journey. The isolation of space heightens the character's own feeling of separation, and the unfamiliar nature of the toroidal space station to the audience will boost the feeling of displacement that the character feels. When the character is brought into more familiar environments (the holographic scene set in a forest clearing), the feeling of relaxation that the character feels will be heightened, at least until the character realizes the environment is intangible.

Design Research

For character and setting design, I've been looking to a number of different fictional and nonfictional sources.

First, I've drawn inspiration from real-world Apollo project and other US space exploration hardware for setting and character design. Specifically, I aim to develop some degree of world-building detail in my settings and characters that reference or emulate real-world hardware. For example, emulating the flight jackets early Apollo and pre-Apollo NASA astronauts would wear in my main character's costume, using the structure and look of Apollo mission control and spacecraft hardware as a basis for the space station, and utilizing the age-old science fiction trick of "kitbashing", which refers to using small, visually interesting pieces from model kits on spacecraft models as undescribed and unexplained surface texture and hardware (known as "greebles").

With all the real world elements, I intend to "filter" the look of the real-world hardware through the same design lens used in midcentury science fiction. "Star Trek" and "Lost in Space" both were television shows aired in the late 1960's which, to varying degrees, emulated the look of Apollo hardware while being limited by their filming budget and influenced by the plastic and saturated design aesthetic of the late atomic/early space age. I plan to use the same saturated color pallet in my setting assets.

Finally, I again draw inspiration from 2001: a space odyssey for my approach to these designs. In 2001, Kubrick collaborated closely with Arthur C. Clarke, who was and is well known for his "hard sci fi" stories, and many aerospace, engineering, and computer companies that existed at the time. Through this collaboration, Kubrick developed a detailed and realistic world that his story could take place in, grounding that story in our real world before Kubrick takes the viewer into the unknown. While I intend to simplify the designs to fit with the space age aesthetic, I still intend to approach the design process within the context of my narrative's "world". Even if this world is never fully revealed to the viewer (which it will not be), internal consistency in the design process will make the final product much more compelling and convincing, and provide grounding that my story can grow out of. As a small example, I start the design process for every panel in the

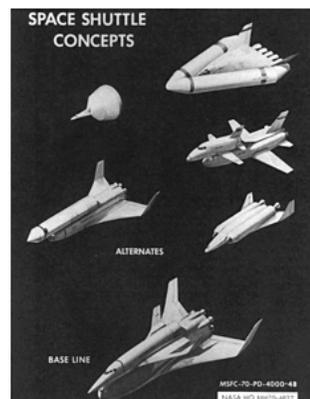
station's "Command Segment" by thinking about what each sub-panel and screen might do or display. This will simplify the later texturing process, where I'll have to come up with some imagery or text to fill these areas.

Design Research Examples

Design Research



Design Research (cont.)



Visual Research (cont.)



Visual Research (cont.)



APOLLO Lunar Module/Command Module

Technical Research & Implementation

In implementing this project, I've looked to a number of sources and done a number of studies to plan out my implementation process and avoid road-blocks where possible.

First, I've organized a spreadsheet to help with the final rendering process of the film. When rendered on a single computer, a 10 second segment can take 3 hours or more to rendered. When distributed to 20 machines, the rendering process could take as little as 10 minutes. The spreadsheet I've developed will help me find the optimal solution to rendering all the shots of my film with the computers I have available, and should give me a good estimate on the amount of time it will take to render everything.

Second, I've been researching techniques to simplify and shorten the texturing and modeling process while also maintaining a detailed look to the film. I looked at the work of visual effects artist Ian Hubert, whose talk at Blend Con 2019 on world building, image texturing, and a number of other techniques has significantly impacted my process in a number of ways.

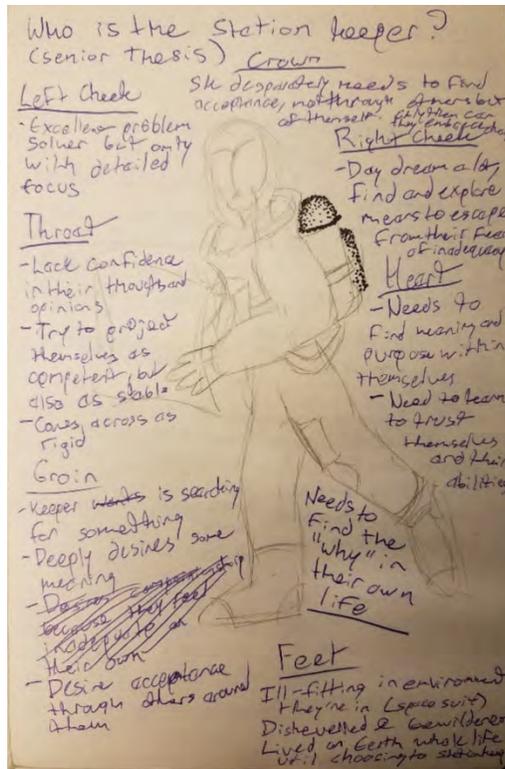
Image texturing specifically has sped my process in a number of ways and increased the detail and realism of the product while also reducing some forms of overhead. Image texturing allows me, as a modeling artist, to use images of real-world objects as textures in my scenes. To restate, it allows me to use a picture of space shuttle tiles to texture a small shuttle which appears in my film. While I could create the same detail and visual interest using the computer or by painting, using real-world source images cuts down on my asset creation time significantly.

Story Development

I choose at the beginning of this project to write my own original story, though writing is not entirely accurate to my process. As already described, I am utilizing an approach to storytelling that relies on character motion and expression more than written dialogue. I wanted to do this because I wanted most of my development process to be focused on animation and the visual elements of the story, rather than specifics of dialogue.

Despite this, the first semester spent on this project largely revolved around story development, and I went through a number of revisions to get to the finished story. To begin the process, I spent a few days studying a number of film review and analysis resources I was familiar with, including the wonderful Youtube channel "Every Frame a Painting", the book "The Hero with a Thousand Faces" by Joseph Campbell, and a number of other sources online and offline. I wanted to start the development process by discovering my characters. Who were my characters going to be? Why would they be like that? Even if the viewer never sees much of the characterization I've done, I felt it important to explore the backstory and motivations of the characters in order to determine how they would behave in the story.

To start with, I did a characterization study of my primary character, the "Station Keeper":



These notes then lead on to influence the first draft of the story. I started the story process by writing out a series of outlines:

Story Lines? Rat for 30 sec at most

Opt 1

- SK arrives at station
- overwhelmed at possibilities
- tries to cope by keeping baggage & memories of past
- Constant holographic contact with Earth
- Communications breakdown

Deluding to pretend like they're still home

Opt 1a Alien friend arrives

- Alien friend is cause of breakdown
- "Spook" of Alien tense scenes as SK & AF play cat & mouse
- Eventually character gives up and collapses, sad
- AF approaches, character is hesitant but not actively fleeing
- AF shows sympathy, gives back servant box
- Bonding!
- SK chooses AF over holo in the end

Focus on picture Billy tips on DZL Multi-Page PDF, not powerpoint

What were doing
Why
What's goals for you
What's goals for viewer
Materials / Methods
Schedule
Context / Influences

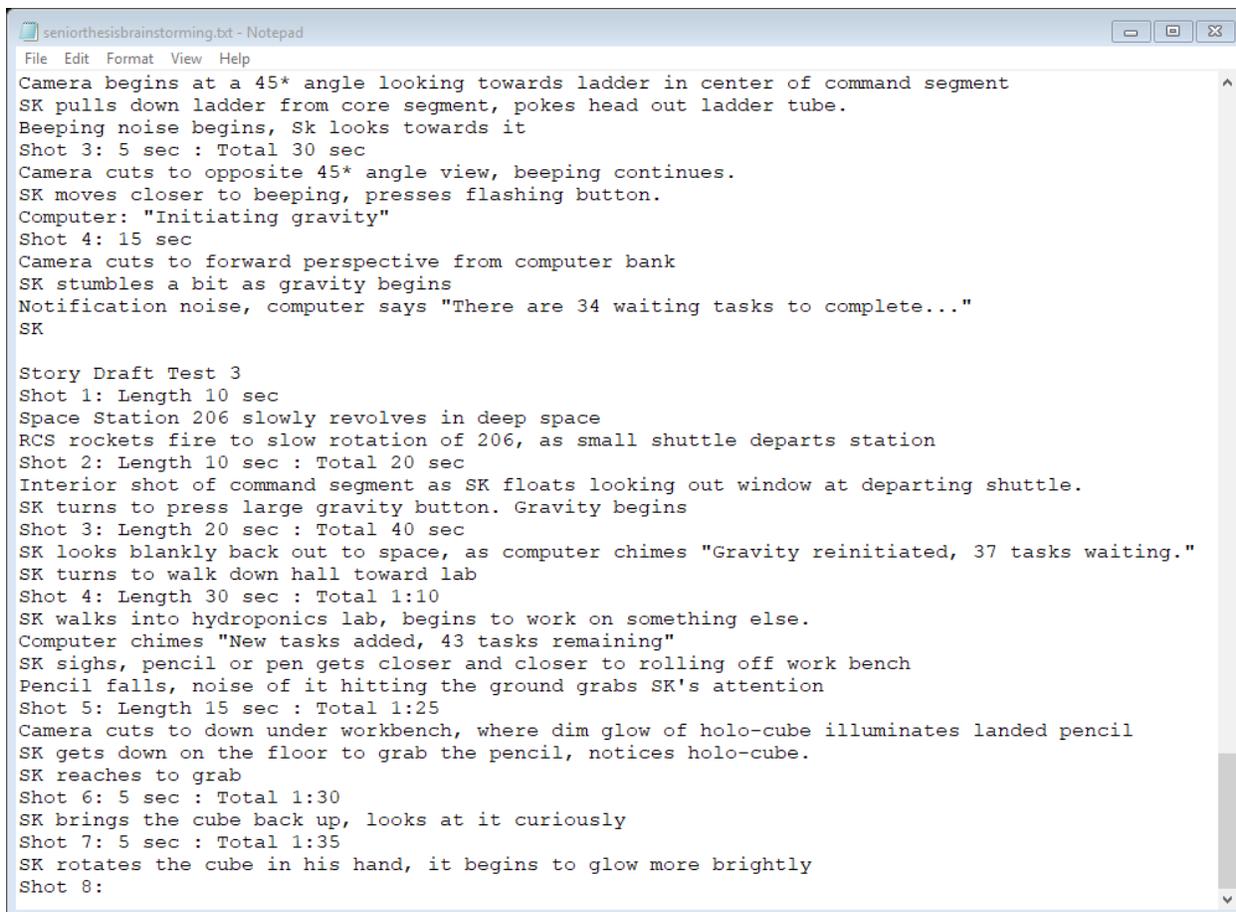
Pros	Cons
- Easier visual narrative with 2 character story	- Common narrative simpler to formulate but maybe not better
- Utilizes context to create psych. cholo delusions, alien as rep from unknown)	- Two hehej don't feel connected? too big of tonal shift
- Play with horror cues	- Avoid Mandt Barbara run

This was then refined into:

```
seniorthesisbrainstorming.txt - Notepad
File Edit Format View Help
Plot:
Segment 1 : Command/Docking Segment
- SK arrives at station on shuttle or some small craft (mostly unimportant to plot). Shuttle docks on side of ring, necessitating zero-g for initial arrival.
- Shuttle departs, and station begins to spin up. This onset of gravity parallels the weight that settles on SK as the reality of their situation sets in.
Segment 2 : Bedroom Segment
- SK is beginning to set up belongings in their personal quarters. First memories of earth appear in form of photographs they paste on bulletin boards, and television broadcast playing over monitor
- SK looks overwhelmed by their environment and the list of things they need to do (physical list?), but finds some comfort in memories (though this ultimately is temporary and only makes their mood worse)
Segment 3 : Living Area/Kitchen segment?
- SK begins using holographic communication equipment to communicate with people on Earth (family, some friends). We see SK finish a conversation with an unnamed figure, and their mood immediately changes following disconnection of the call.
- SK solemnly finishes eating their meal, looking depressed into it.
Segment 4 : Lab Segment
- SK walks into lab which has some hydroponics equipment. (maybe look at their physical todo list?) SK disregards the things they need to do and activates a holographic forested environment. This is a muted representation of a natural environment on Earth
- For some time SK enjoys this environment, gently smelling the few real plants in the room. But soon the holographs flicker and die as an object strikes the station. Red alert sounds.
- SK is alarmed and distraught at the loss of the forest, but soon rushes to the left toward the command segment to try to figure out what has happened.
Segment 5 : Command/Docking Segment 2
- SK arrives at command segment, but is unsure what the cause of the trouble is (minus big red "COMMS FAILURE" on each of the screens).
- Some visual communication to continue left, so SK continues left.
Segment 6 : Mechanical Segment
- Ominous plap plap noises abound as SK enters room (maybe with flashlight for dramatic effect).
- SK searches around room for source of noise and cause of issue
- At about this time we begin to have gravity deactivation (perhaps telegraphed by computer narrator? or status screens)
- AF plops in and out around SK's peripheral vision as scene goes on.
- Eventually SK sees AF, and
```

After I had this written version, I refined the plot into the first storyboard. But after developing the story this far I found myself dissatisfied, and the length and complexity of the story was spiraling out of control. So I began to simplify the story. I spent two weeks thinking about the story and trying to determine what it's point was; i.e., what is the story about? I began to focus on the idea of escapism. Essentially, the character in the first draft of the story is looking to escape from their responsibilities and their emotions by living in the past. They can't move on from a past that they can no longer access, and don't want to embrace their current living situation.

So once I determined this as the point of the story, I went back to writing:



```
seniorthesisbrainstorming.txt - Notepad
File Edit Format View Help
Camera begins at a 45* angle looking towards ladder in center of command segment
SK pulls down ladder from core segment, pokes head out ladder tube.
Beeping noise begins, Sk looks towards it
Shot 3: 5 sec : Total 30 sec
Camera cuts to opposite 45* angle view, beeping continues.
SK moves closer to beeping, presses flashing button.
Computer: "Initiating gravity"
Shot 4: 15 sec
Camera cuts to forward perspective from computer bank
SK stumbles a bit as gravity begins
Notification noise, computer says "There are 34 waiting tasks to complete..."
SK

Story Draft Test 3
Shot 1: Length 10 sec
Space Station 206 slowly revolves in deep space
RCS rockets fire to slow rotation of 206, as small shuttle departs station
Shot 2: Length 10 sec : Total 20 sec
Interior shot of command segment as SK floats looking out window at departing shuttle.
SK turns to press large gravity button. Gravity begins
Shot 3: Length 20 sec : Total 40 sec
SK looks blankly back out to space, as computer chimes "Gravity reinitiated, 37 tasks waiting."
SK turns to walk down hall toward lab
Shot 4: Length 30 sec : Total 1:10
SK walks into hydroponics lab, begins to work on something else.
Computer chimes "New tasks added, 43 tasks remaining"
SK sighs, pencil or pen gets closer and closer to rolling off work bench
Pencil falls, noise of it hitting the ground grabs SK's attention
Shot 5: Length 15 sec : Total 1:25
Camera cuts to down under workbench, where dim glow of holo-cube illuminates landed pencil
SK gets down on the floor to grab the pencil, notices holo-cube.
SK reaches to grab
Shot 6: 5 sec : Total 1:30
SK brings the cube back up, looks at it curiously
Shot 7: 5 sec : Total 1:35
SK rotates the cube in his hand, it begins to glow more brightly
Shot 8:
```

After I did this, I went back to storyboarding and produced the following result:

Version 2

Ext Space Station

(5 sec)



Starfield encompasses station.
Station spins slowly

Ext Space Station, Shuttle

Particle Sim

(4 sec)



Station fires rockets
and slows to a stop

Ext Space Station, Shuttle
Particle Sim (6 sec)



A small shuttle begins
to pull away & leave
the station

(cut)

Scene: 1 Page: 1

Total scene Time: 0:15
Total Run Time: 0:15

Version 2

Int Command Seg, SK,
Zero Gee (3 sec)



Orange glow fades from SK's face as rockets fire and shuttle proceeds. SK watches the shuttle

Int Command Seg, SK
Zero Gee (3sec)



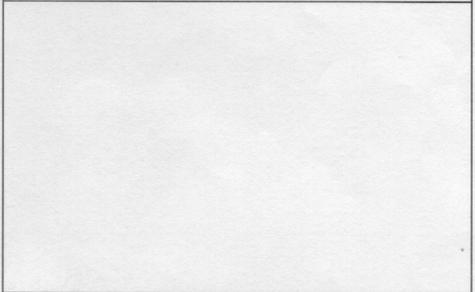
Computer Says "Departure sequence completed, SK removes headphones, then sighs

Int Command seg, SK
Zero Gee → Full Gee (6 sec)



SK presses a button, Computer says "gravity reinitializing", SK looks at tables

Int Command seg, SK
Zero Gee



Scene: 3 Page: 1

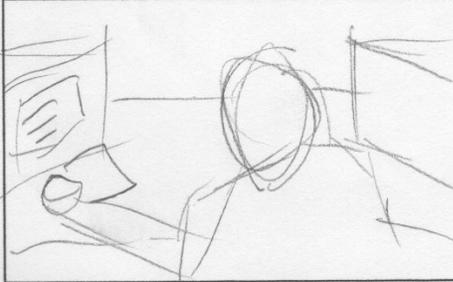
Total Scene Time: 0:12
Total Run Time: 0:32

Int Command Seq, SK
Full Gee (5sec)



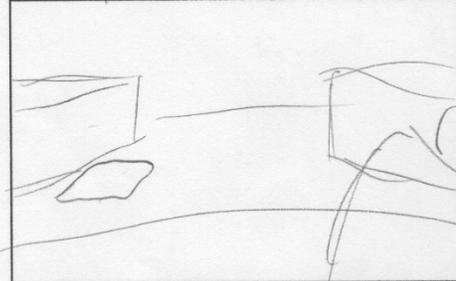
SK momentarily looks at tablet & sighs, Computer says "37 tasks remaining"

Int Command Seq, SK
Full Gee (4sec)

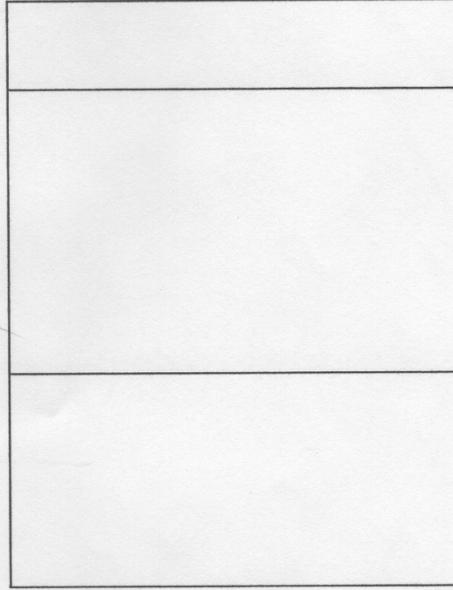


SK presses Dismissor Snooze button, possibly telegraphed by computer saying "remainder deferred"

Int Command Seq, SK
Full gee (3sec)



SK gets up to leave leaving tablet on snooze button
(cut)



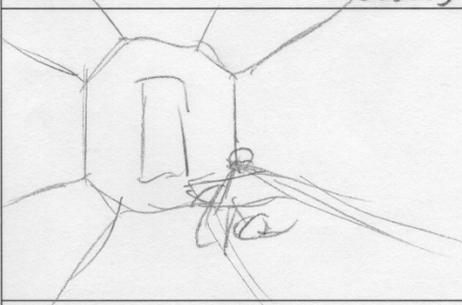
Version 3

Int Living Seq, SK,
Photos (4sec)



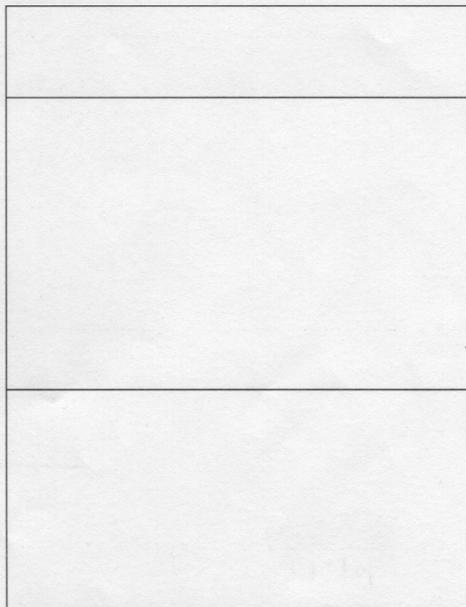
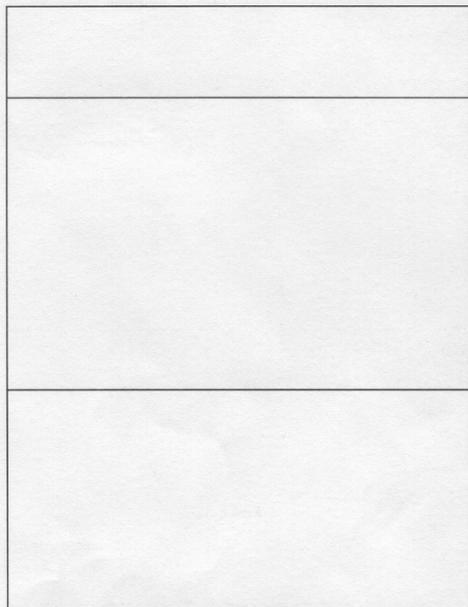
SK walks through to
living seq with head down,
annoyed expression,

Int Living Seq, SK
Photos (3sec)



SK goes to sit in
his desk chair

cut ->



Scene: 5 Page: 1

Total Scene Time: 0:07
Total Run Time: 0:51

Int Living seg, Sk
Photos (6sec)



Sk sobs in his chair, hits snooze button when computer announces "49 tasks waiting"

Int Living seg, Sky
photos, hologram (8 sec)



Sk reaches out for holo-cube on his desk, ^{→ activates it} expression softens somewhat, then he looks deeply sad

Int Living Seg, Sk
Photo (4sec)



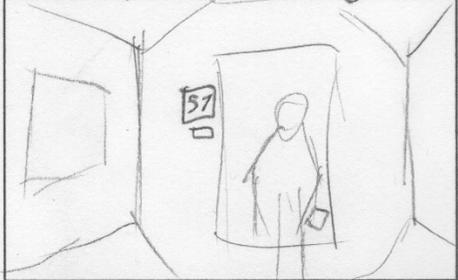
Sk slams snooze button and puts down holo-cube when computer sounds "53 tasks waiting"

Int Living Seg, Sk
Photo (5sec)



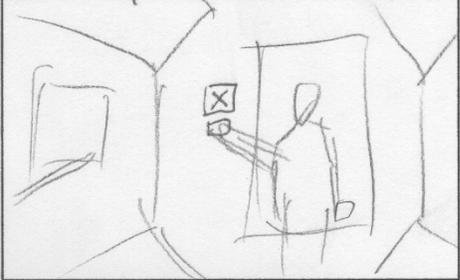
Sk gets up to leave, takes holo-cube with him
cut →

Int Living Seg, Sk
Looking into Rec ~~Bag~~ (7sec)

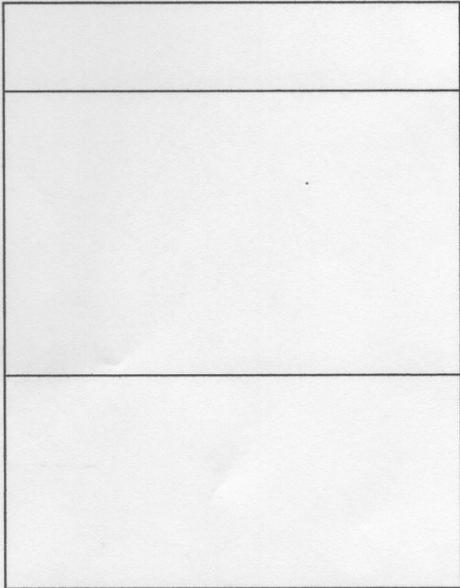
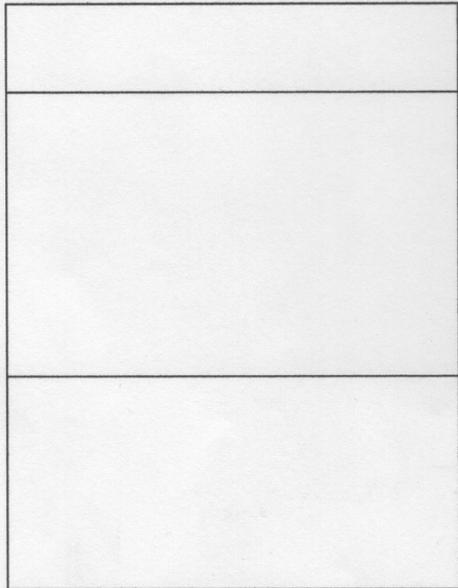


Computer says "57 tasks remaining. Recreational segment can not be ..." as Sk approaches door, carrying Holocube

Int Living Seg, Sk
Looking into Rec Room (3sec)

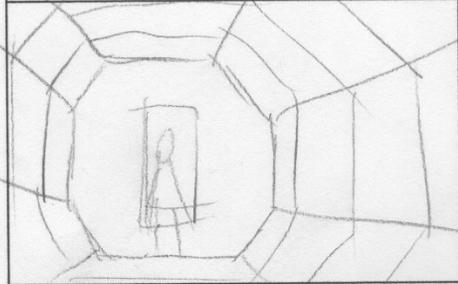


Computer says "Overridden" as Sk presses snooze button, begins to step through



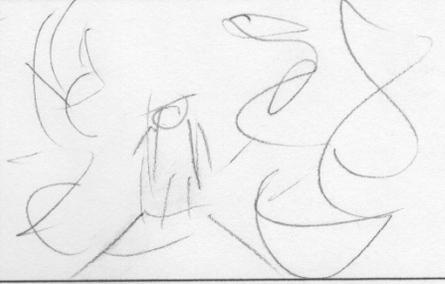
Version 3

Int Rec Seg, SK
(6 sec)



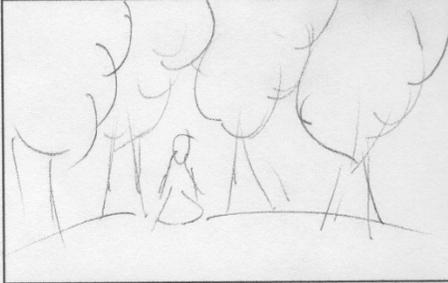
SK finishes stepping into
rec room, pulls out "holo
crystal" and activates

Int Rec Seg → Forest Ext, SK
Hologram
(3 sec)



Machines power up,
hologram begins to
form around SK

Ext Forest, SK
Hologram
(6 sec)



SK falls to knees,
after basking in fake
glow of the fake forest

Scene: 8 Page: 1

Total Scene Time: 0:15
Total Run Time: 1:39

Ext Forest, Sk
Hologram (3sec)



Sk looks on verge of tears at sight of forest

Ext Forest, Sk
Hologram (5sec)



Sk closes eyes, ambient sound muffles, and expression changes from happy to sad/blank

Ext Forest, Sk
Hologram (5sec)



Computer says "Alert waiting," Sk looks annoyed

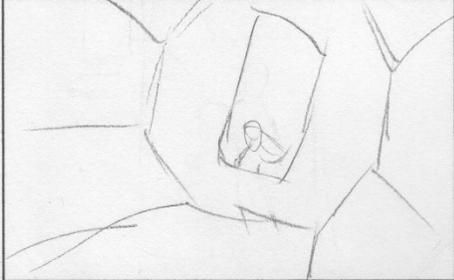
Int Rec Seq ← Ext Forest, Sk
Hologram (4sec)



Crash hits station, Sk is jolted, falls over

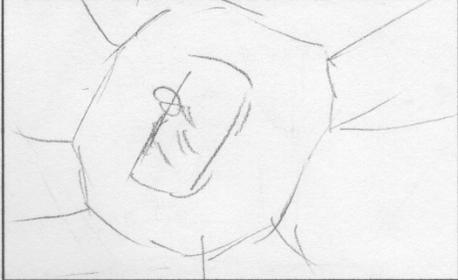
(3sec)

Int Living seg, Sk
Looking into Rec Seg (6sec)



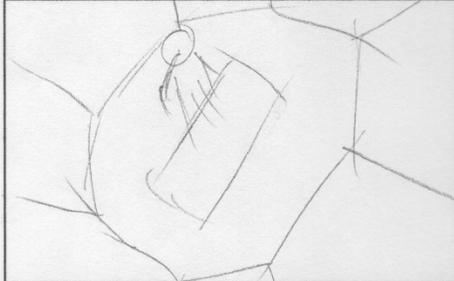
Sk gets up from floor at hologram room, begins to move back through seg.

Int Living Seg, Sk
Looking into Rec Seg → Zerogee

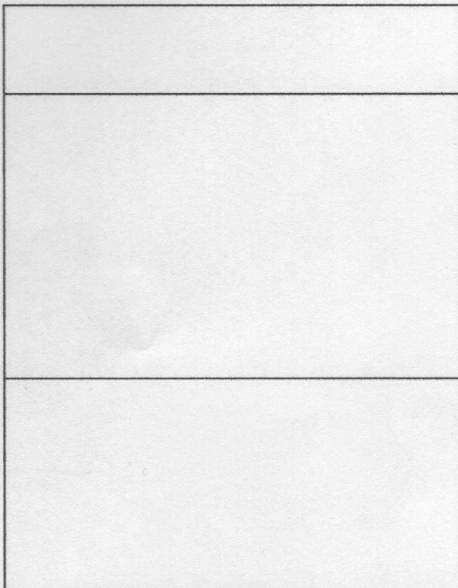


Station creaks as gravity fails, Sk has to pull himself down hall

Int Living Seg, Sk
Zero Gee (4sec)

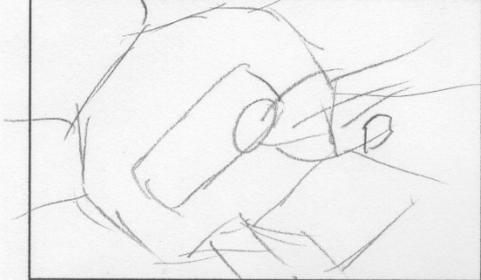


Sk flies past camera, holocube in hand



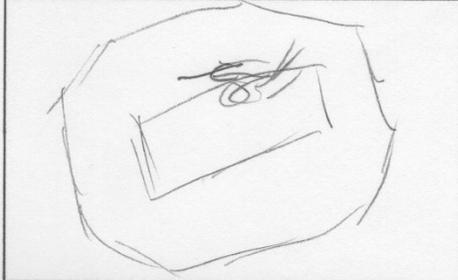
Version 3

Int Cmd Seg, sk
Zero Gee (6sec)

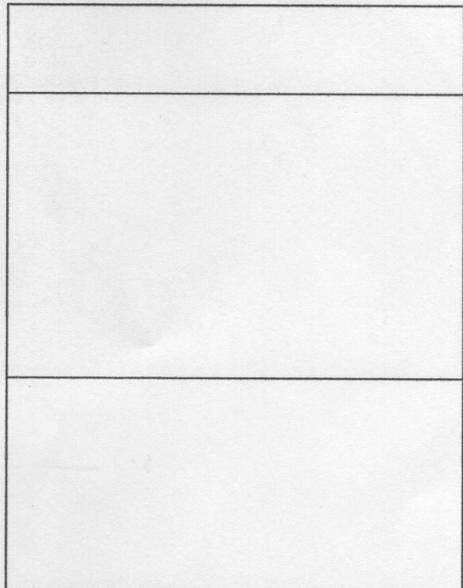
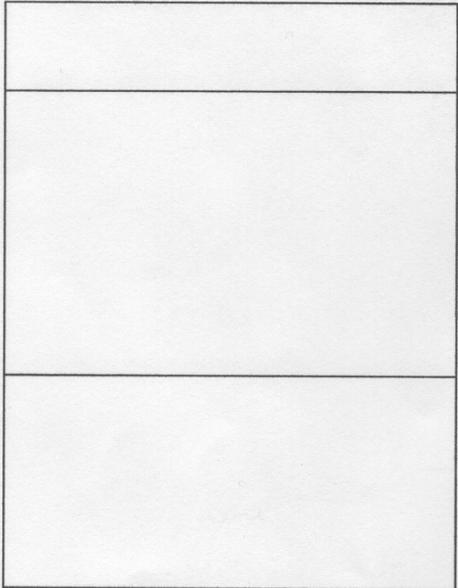


sk flies towards
maint seg door.

Int Cmd Seg, sk
Zero Gee (6sec)



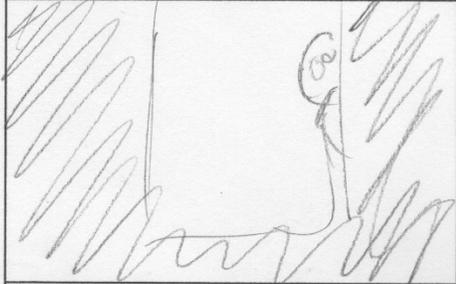
sk catches on
handle, looks into
room.



Scene: 11 Page: 1

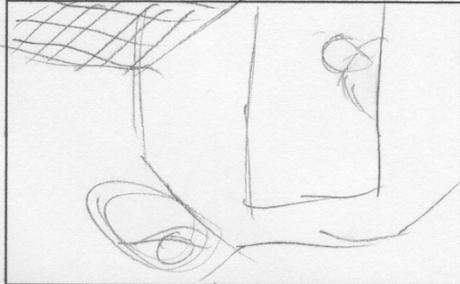
Total Scene: 0:12
Total Run: 2:21

Int Maint Seg, SM
Zero Gee (6sec)

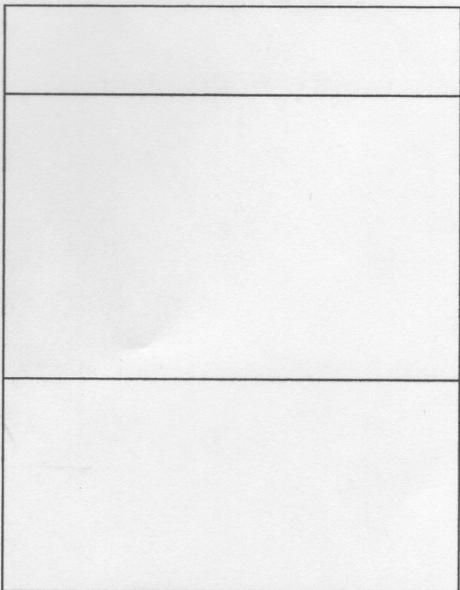
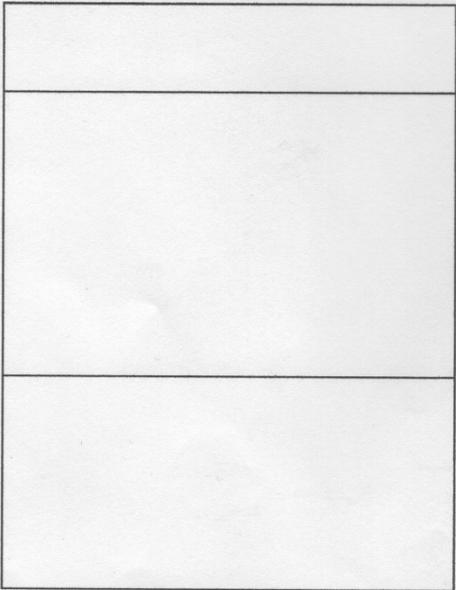


SM poles head into room, looks very surprised.
A dull yellow glow pulses
Zoomat →

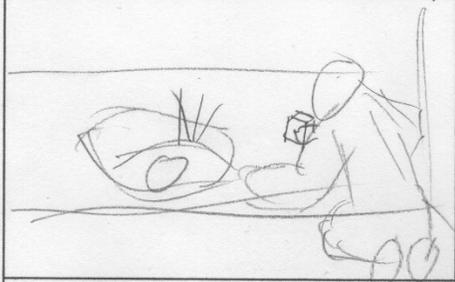
Int Maint Seg, SN, WT
Zero Gee (6sec)



Force Field pulses above robot ^{WT} guy, who has sparks coming out.

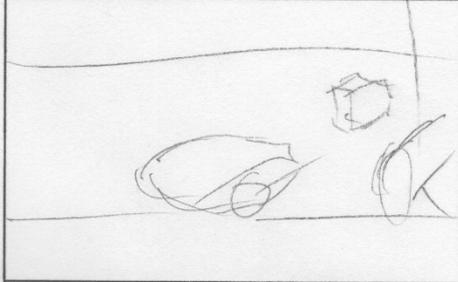


Int Maint seg, Sk, WT
Zero Gee (4sec)



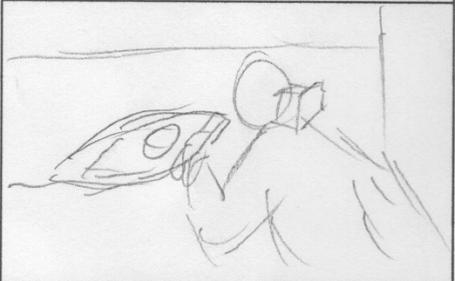
Sk moves towards
WT, notices broken comp.
and flashing indicator which
is slowly leveling down

Int Maint seg, Sk, WT
Zero Gee (6sec)



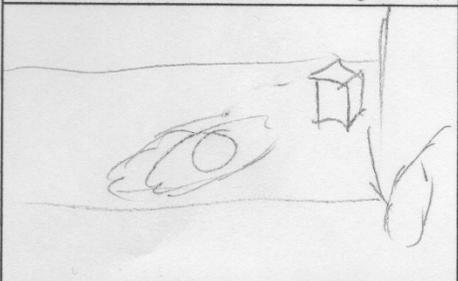
Sk moves to grab
something, WT notices
HoloCube and tries to
wobble towards it

Int Maint seg, Sk, WT
Zero Gee (6sec)



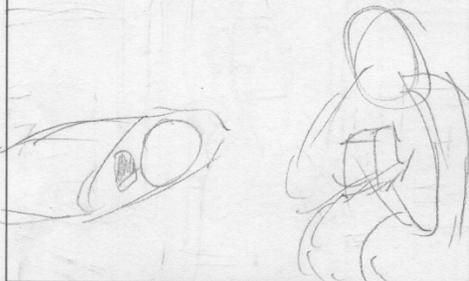
Sk returns, asks if WT
can use a battery.
WT shakes head to signal
"no"

Int Maint seg, Sk, WT
Zero Gee (4sec)



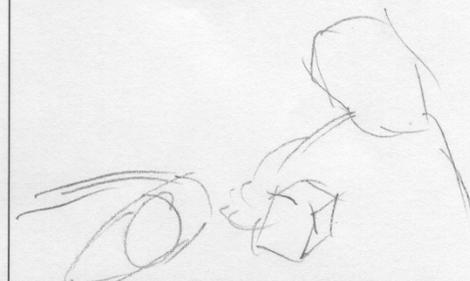
Sk again moves to grab
something, even more
urgently. WT wiggles towards
HoloCube again.

Int Maint seq, sky WT
Zero Gee (6sec)



Sk hesitates, holds holocube closely, WT wiggles closer

Int Maint seq, sky WT
Zero Gee (8sec)



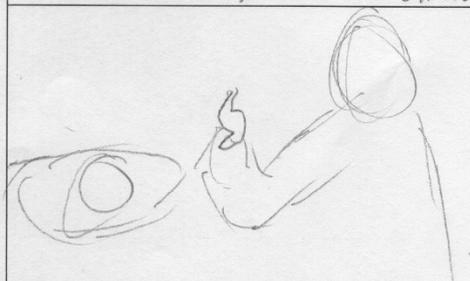
Sk looks sadly at Holocube, looks at WT, then sighs

Int Maint seq, sky WT
Shatter Holocube, Zero Gee (8sec)



Sk uses a nearby hammer to shatter Holocube, but it takes a few hits (maybe don't show shatter)

Int Maint seq, sky WT
Shatter Holocube, Zero Gee (4sec)



Sk holds up holocystal, begins to move towards WT's ~~shattered~~ broken components

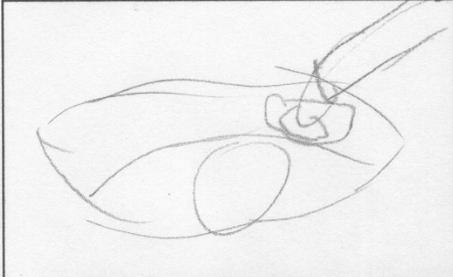
Total Scene Time: 0:26

Scene: 14 Page: 1

Total Run Time: 3:23

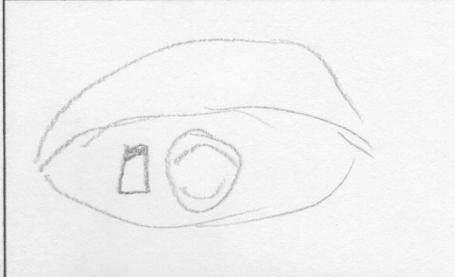
Version 3

Int Maint seg, Sk, WT
Zero Gee (5 sec)

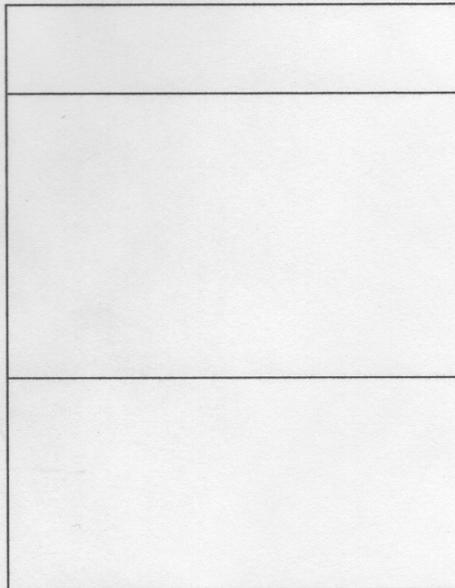
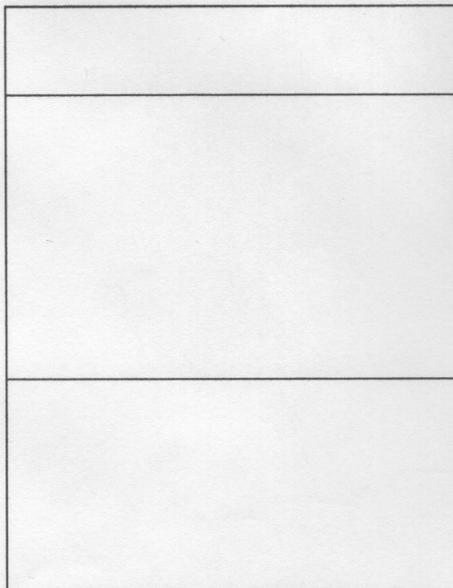


Sk places crystal
in WT

Int Maint Seg, Sk, WT
Zero Gee (5 sec)



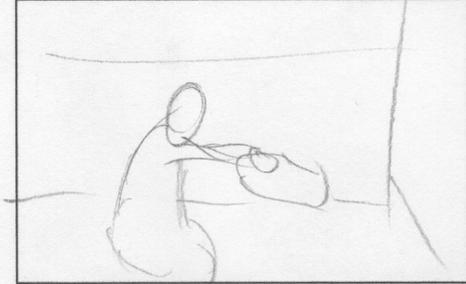
WT's systems shudder
to life, coloring of indicators
suggests happiness



Scene: 15 Page: 1

Total Scene Time: 0:10
Total Run Time: 3:33

Int Maint Seg, SK, WT
WT (5sec)



SK pats WT, they
look happy

Int Maint Seg, SK, WT
Zero Gec (3sec)



Station shudders, computer
states "Critical tasks
waiting, warning! 12 tasks
waiting!"

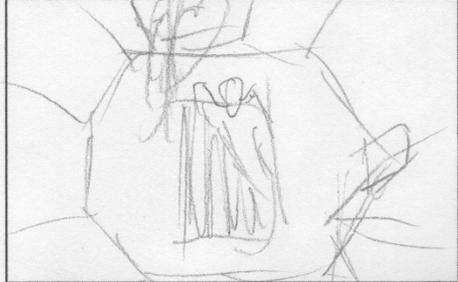
Int Maint Seg, SK, WT
(4sec)



SK moves to follow WT,
who zips away

"101 tasks remaining"

Int Command Seq
Sk, WT, Zero Gee (4sec)



Sk drifts towards broken equipment to make repairs
"93 tasks remaining"

Int Command Seq, Sk, WT
Zero Gee (3sec)



WT darts in and fixes broken equipment quickly
"84 tasks remaining"

Int Command Seq, Sk, WT
Zero Gee (4sec)



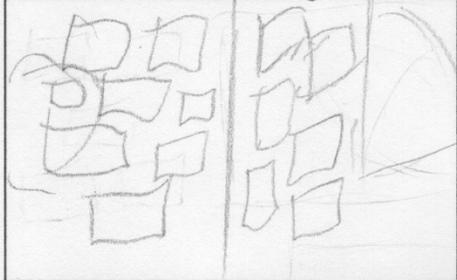
WT darts around the cabin connecting problems
Sk laughs at first but then sighs "63 tasks remaining"

Int Command Seq, Sk, WT
Zero Gee (6sec)



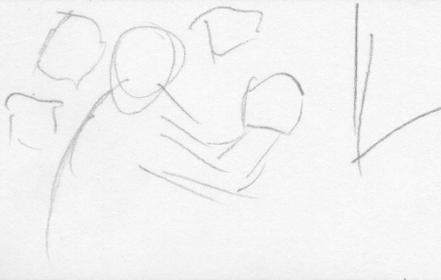
After WT darts away, Sk drifts towards living area
"51 tasks remaining"

Int Living seq, sk
Photos Zero Gee (6sec)



Sk drifts towards pictures and looks at them on wall longingly
"23 tasks remaining"

Int Living seq, sk
Photos Zero Gee (6sec)

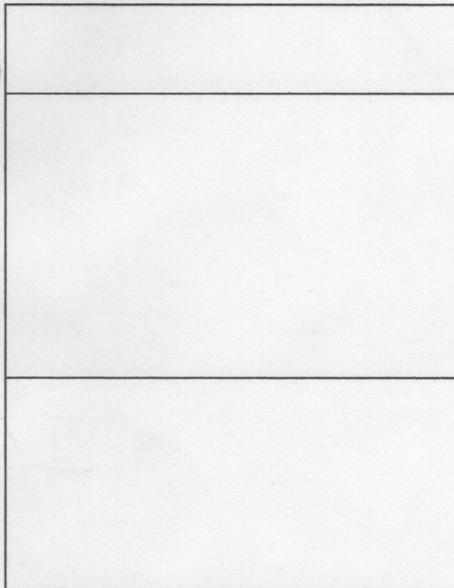


Photos noticeably drift, Sk looks at one picture in particular (Same as on holocube)
"4 tasks remaining"

Int Living seq, sk
Photos Zero Gee → Full (4sec)



Sk falls as gravity turns back on.
"Gravity reinstated.
1 task remaining."



Version 3

Int Living Seq, Sk
Photos (5sec)



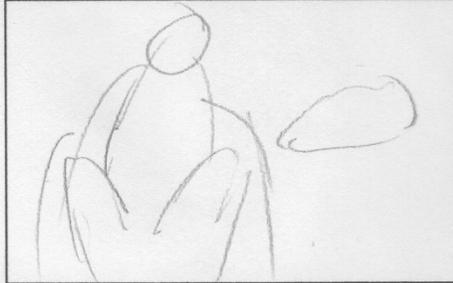
Pictures fall onto
sk, who again
sulk
"1 task remaining"

Int Living Seq, sk, wt
Photos (6sec)

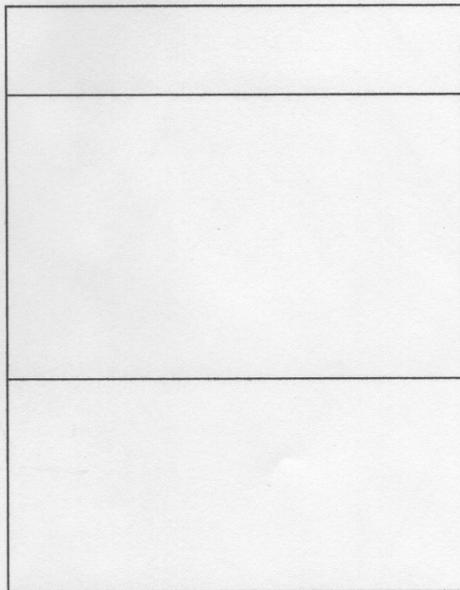


Hear squeaking of wt,
who nudges on sk's
knee to "get up!"
"1 task remaining"

Int Living Seq, sk, wt
Photos (3sec)



sk begins to get
up, wt follows

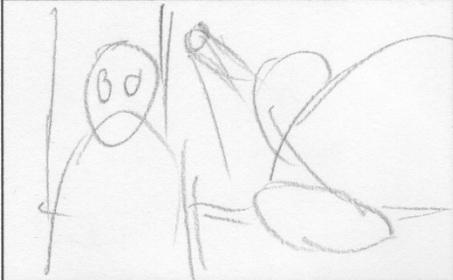


Scene: 19 Page: 1

Total Scene Time: 0:14
Total Run Time: 4:32

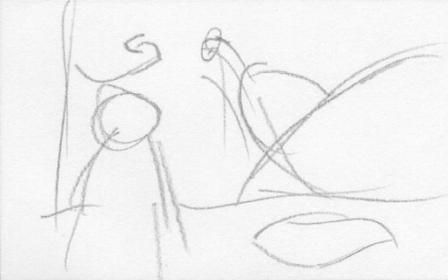
Version 3

Int Living seq, WT, Sk
(3sec)

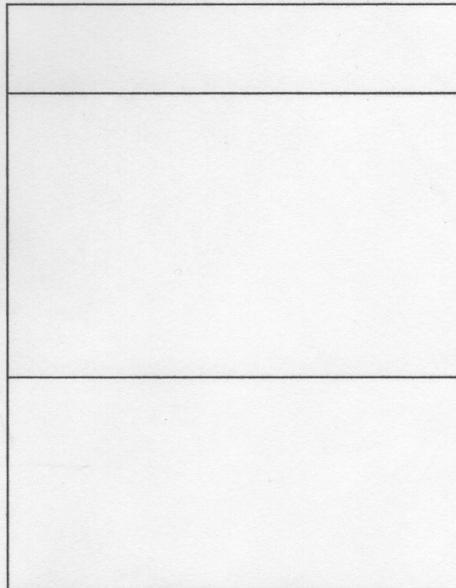
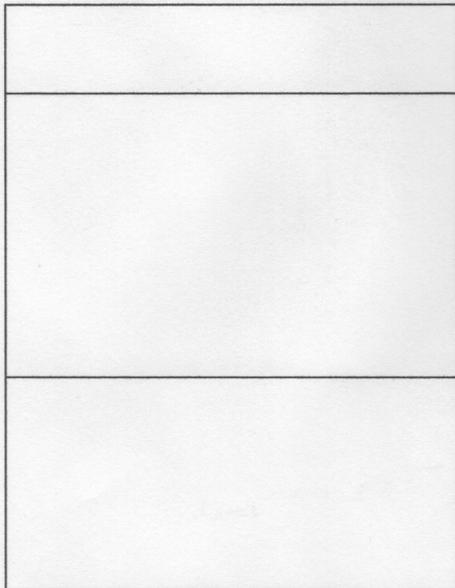


Sk finishes standing
WT points to window
outside is out of focus

Int Living seq, WT, Sk
(3sec)



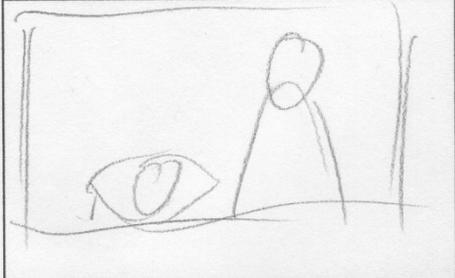
Sk looks out
window, universe
comes into focus



Scene: 20 Page: 1

Total scene Time: 0:06
Total Run Time: 4:38

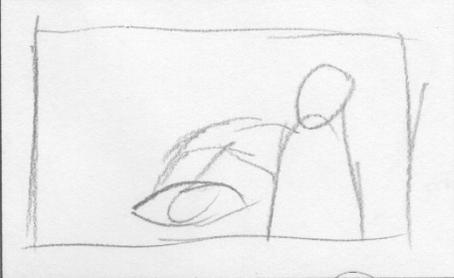
Int Living / SK, WT
↳ Ext Station (4sec)



SK's expression softens greetchly

Zoom out →

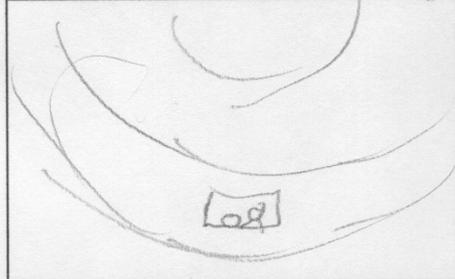
Int Living SK, WT
↳ Ext Station (6sec)



SK pats WT, smiles.
Computer says "Task list complete"

Zoom out →

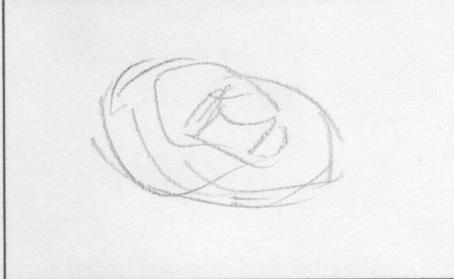
Ext Station SK, WT
(4sec)



See SK, WT fade as whole station comes into view

Zoom out →

Ext Station (6sec)



Final image of station slowly spinning in space

Asset Development

I worked on asset development concurrently to story development, primarily developing the characters and set I would need for the story. Thankfully, I was able to attain pre-made models for both of my film's characters, so I did not have to put very much effort into getting the characters ready for animation. I had to start development on my film's settings from scratch, however, so much of my time working on asset development was spent on the setting assets.

First, for my film's main character I found a rig and model called "Ivan" by Blender Artist Nikolai Mamashev. This rig comes with a very nicely constructed and textured character model:



To create my film's character, I just retextured the character, changing it from its original clothing to much more "space-y" clothing:

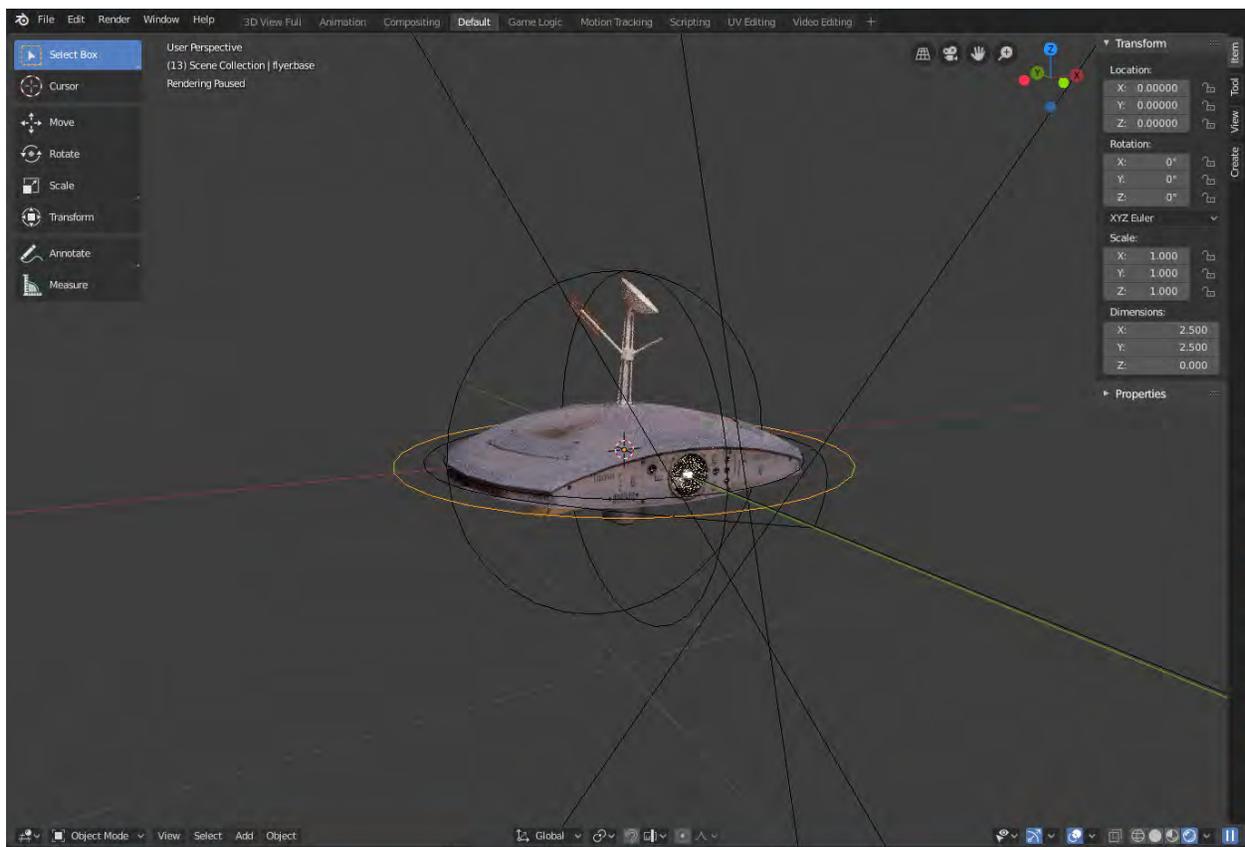


Namely, I recolored the character's pants to change them to a khaki-like color, and the character's hair to be much less saturated. I also redid the character's jacket to look like Apollo era and pre-Apollo era flight jackets given to astronauts to wear in publicity pictures:

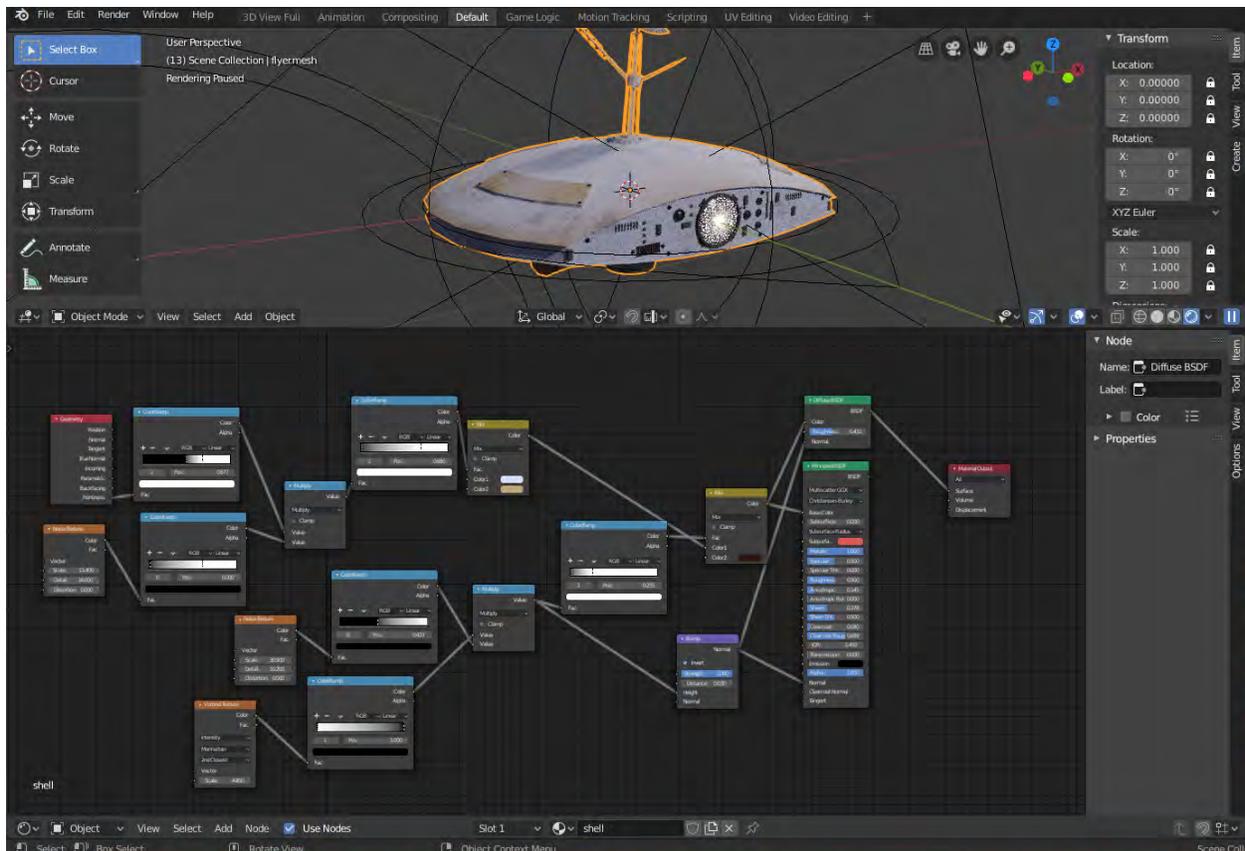


Second, for the robotic character I was able to locate and update a character I had made for my Animation 3 class. Much of the development process for this character model has gone into adapting the character's shaders (i.e., the programming that tells the software how the surface of an object looks) and rig (i.e., the structures that allow a character to move) from the version of the software the character was created in to the current version of the software.

As it originally appears, the character was shaded like this:



I was mostly unhappy with how the shaders look in this version, so when I began updating I chose to completely replace the shaders on the model rather than update them to the new version. Thankfully the character's rig was mostly working so not much effort had to go into updating that. At present, the robot character looks like this:

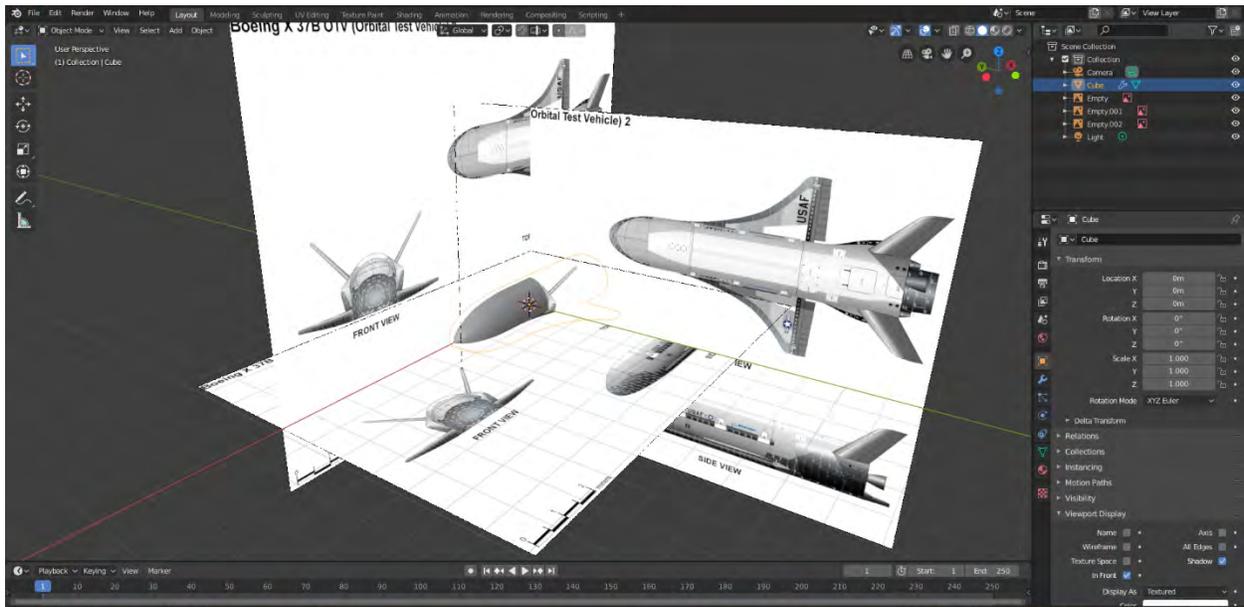


The web of blocks on the bottom of the screen are a representation of the code that the computer uses to determine how the surface looks. This is still much too complicated to render quickly, and it doesn't really match the planned aesthetic of the rest of the film. So I plan to do further work on this character model as the project progresses.

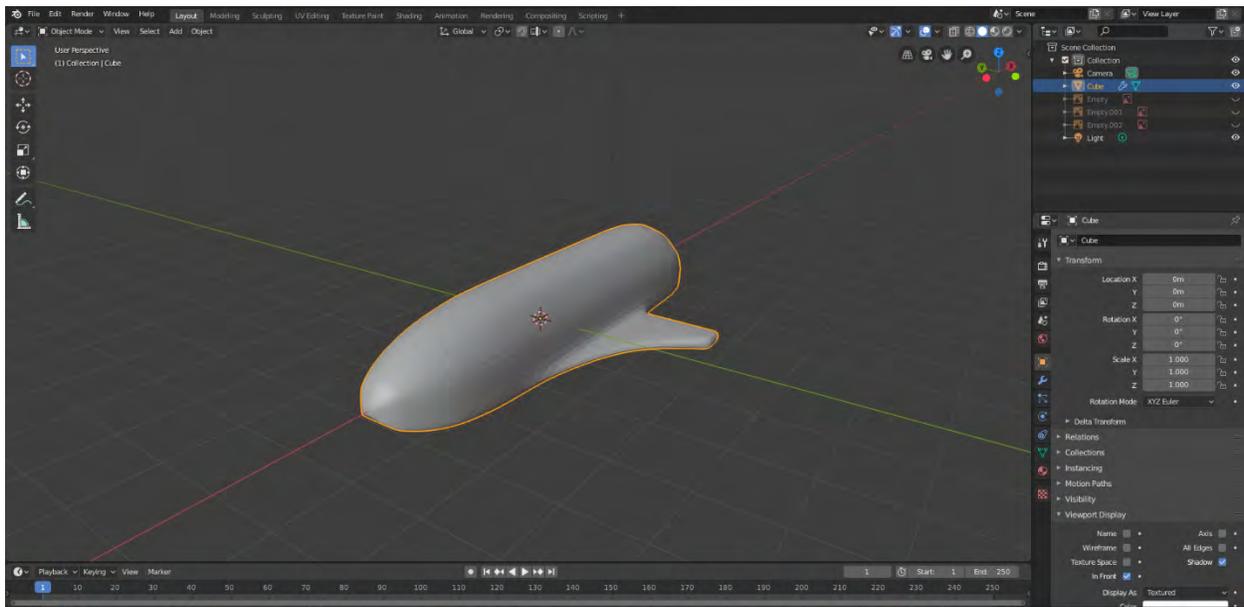
I also have a number of smaller assets that are not settings but are also not characters. I've developed these assets from scratch. For all of these assets, there's a roughly 3 phase process that I've gone through to get them ready for use. First, the asset must be modeled, meaning that I must construct the geometry of the object from basic polyhedrons such as cubes, cylinders, etc. This can be done from a reference or from scratch. Second, the asset must be shaded and textured, meaning that I must construct a surface for the object using the shader coding seen above and painted or image textures. Third, the asset must be rigged for animation.

The first asset, a small passenger shuttle, has gone through all of these phases (though is not quite complete). To begin with, I modeled the shuttle utilizing

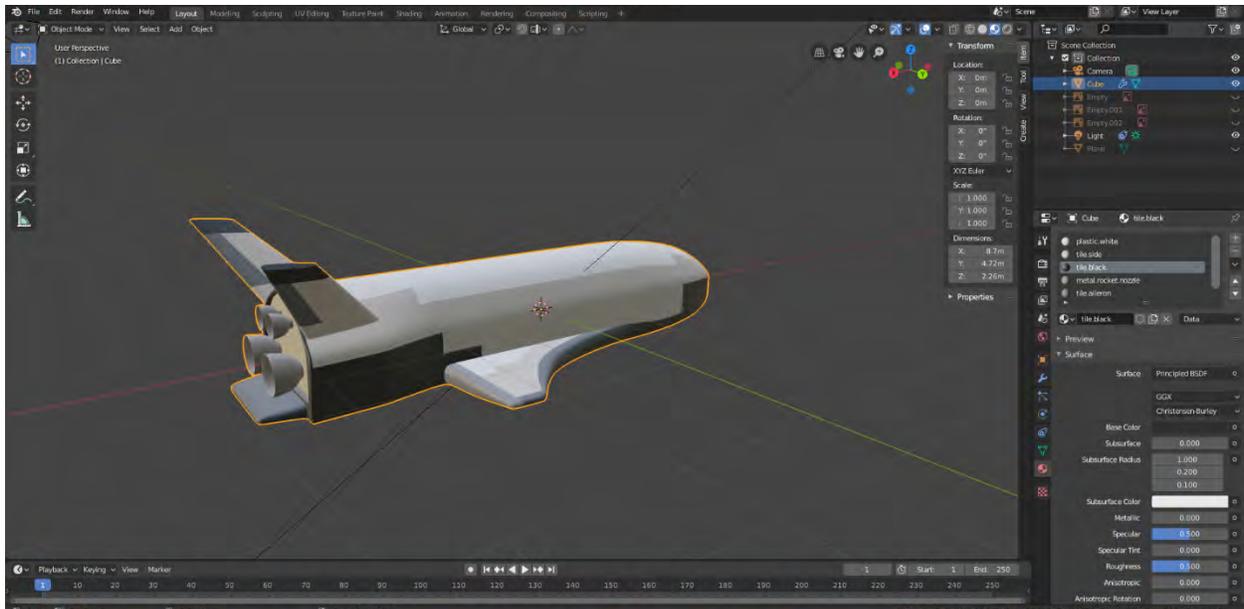
diagrams of the Boeing X-37 space plane as a base. You can see the reference in the following image in the form of large image planes that envelop the model:



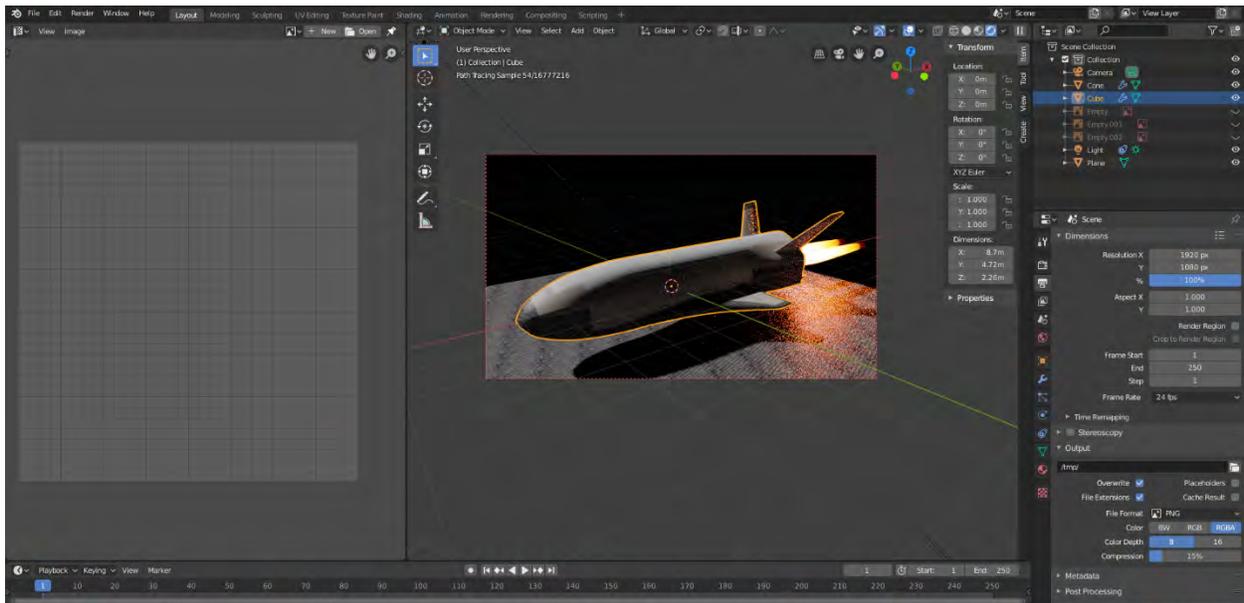
Without the image reference, in this early version the model looks like this:



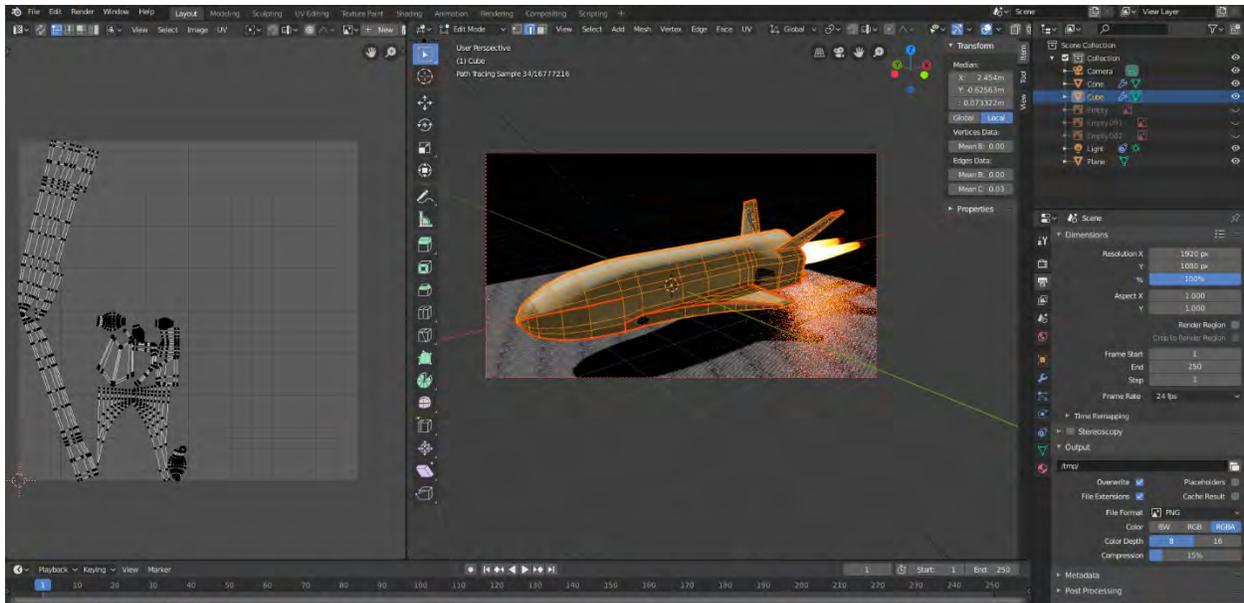
After a little more work, plus some basic shading, the model looks like this:



I then added a separate model to serve as rocket exhaust, which when shaded looks like a volumetric flame object:



And prepared the model to accept image textures using a process known as UV mapping:



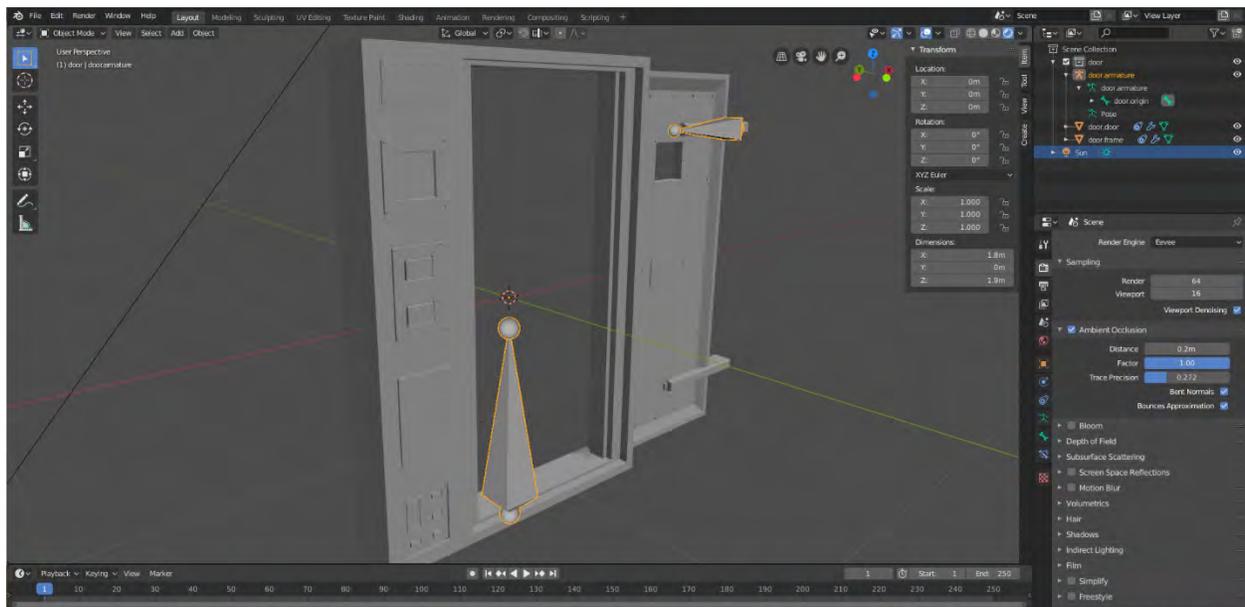
UV Mapping, in a very rough sense, unwraps the geometry in the model as if it was a paper construction. Where the unwrapped geometry falls on the image plane to the left is where an image applied to that area would be applied to the model. It's a very technical process that ultimately just allows the artist to place images on the surface of the model.

Finally, I rigged this shuttle model to allow rotation and translation of the shuttle itself and scaling of the rocket exhaust object (to simulate engine throttle):



The rig is visualized by various bones, which are the strange green objects which are super-imposed on top of the model.

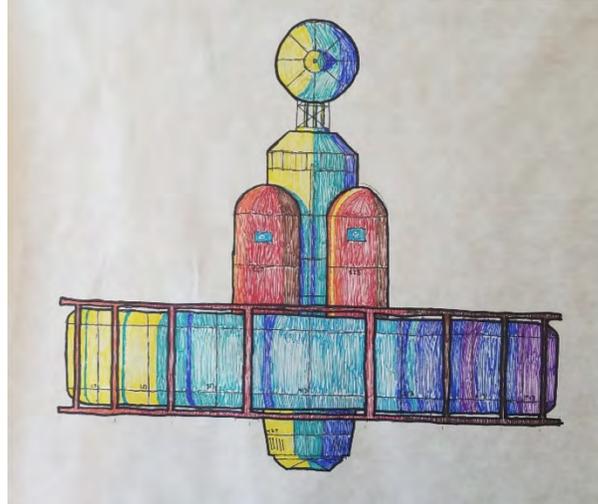
I've followed this same process to construct the door which shows up throughout the space station interior. The final product of the modeling and rigging phase can be seen here:



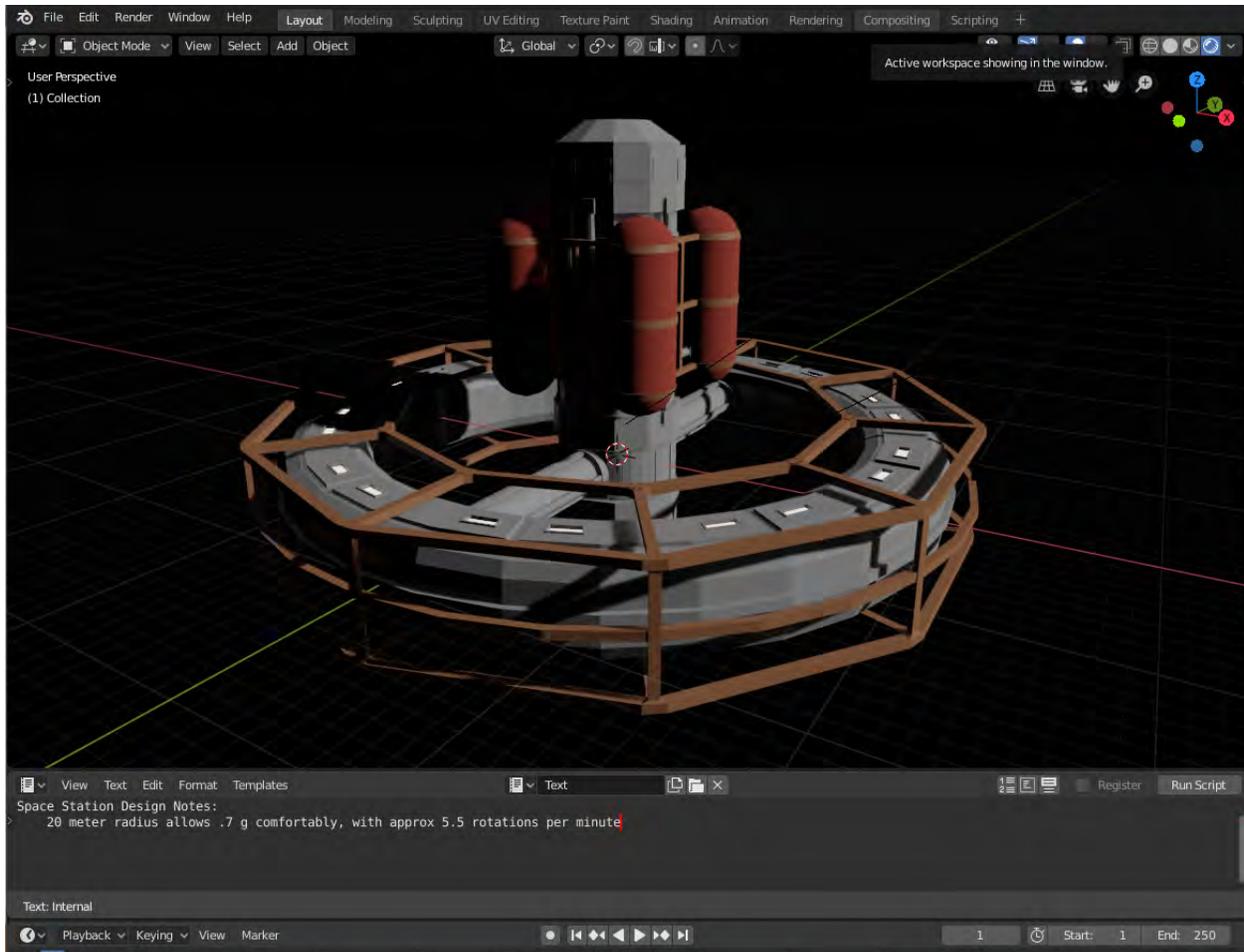
Due to time restraints, the door has not been completely surfaced. However, base colors have been placed on all surfaces as can be seen here:



For the interior and exterior of the space station used as a setting in the film, the development process is identical. For the exterior, I first created a sketch to use as a base design for the space station:



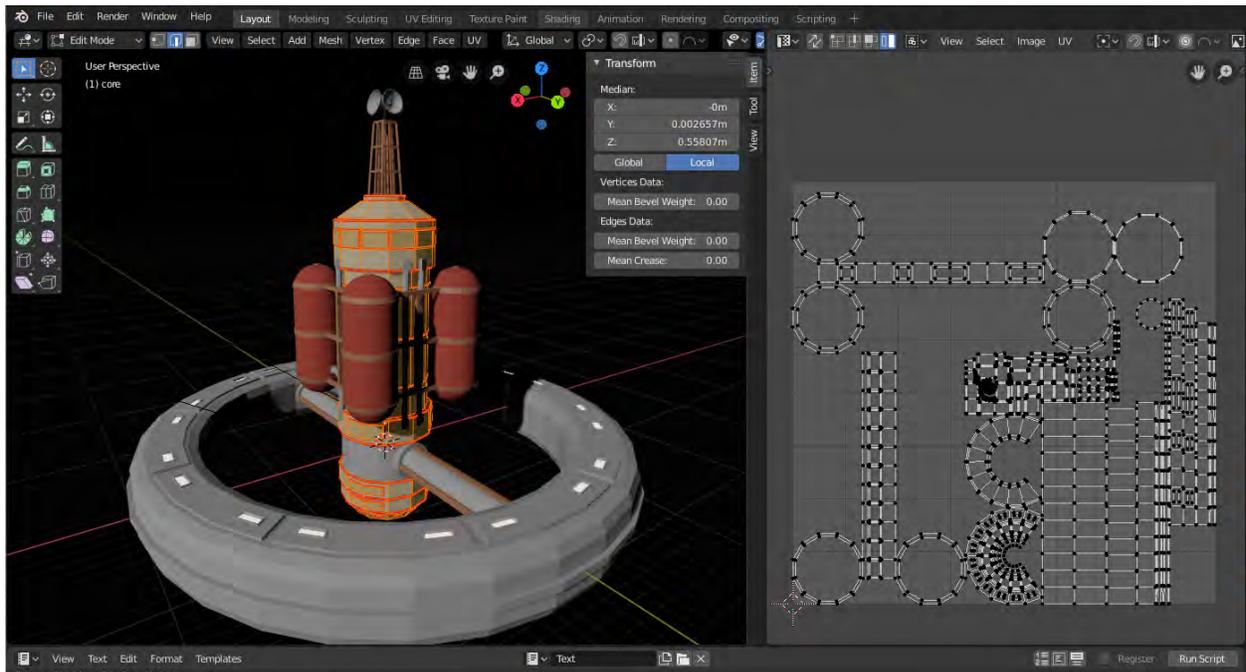
I then modeled using this sketch as an inspiration for what the final model might look like, while also considering what the physical reality of the structure of the space station might be to inform the design process. In the first iteration, the station looked like this:



The brown framework around the habitable section was initially created to serve as a cinematographic device to transition between periods of time in the first half of the story. As the story changed and I stopped using that element, the framework became unnecessary and visually clunky, so in later revisions I removed it:



At this point I also went ahead and did the UV unwrapping stage of the model development:



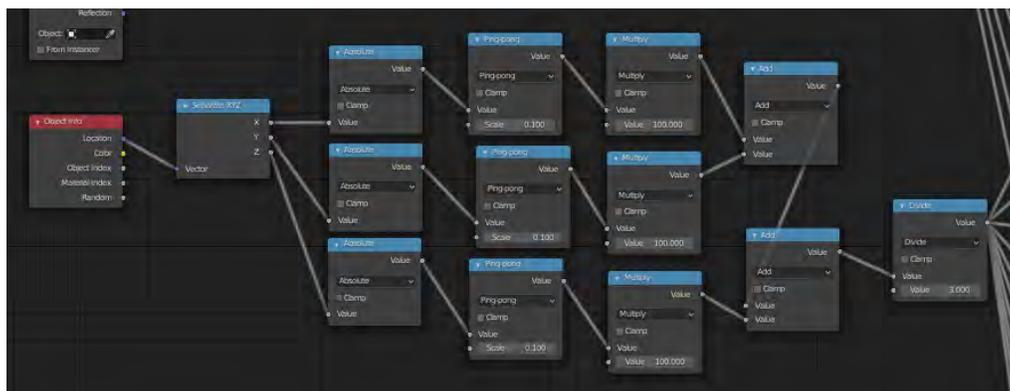
Because the space station exterior is composed of separate models, separate UV maps had to be made for each constituent model.

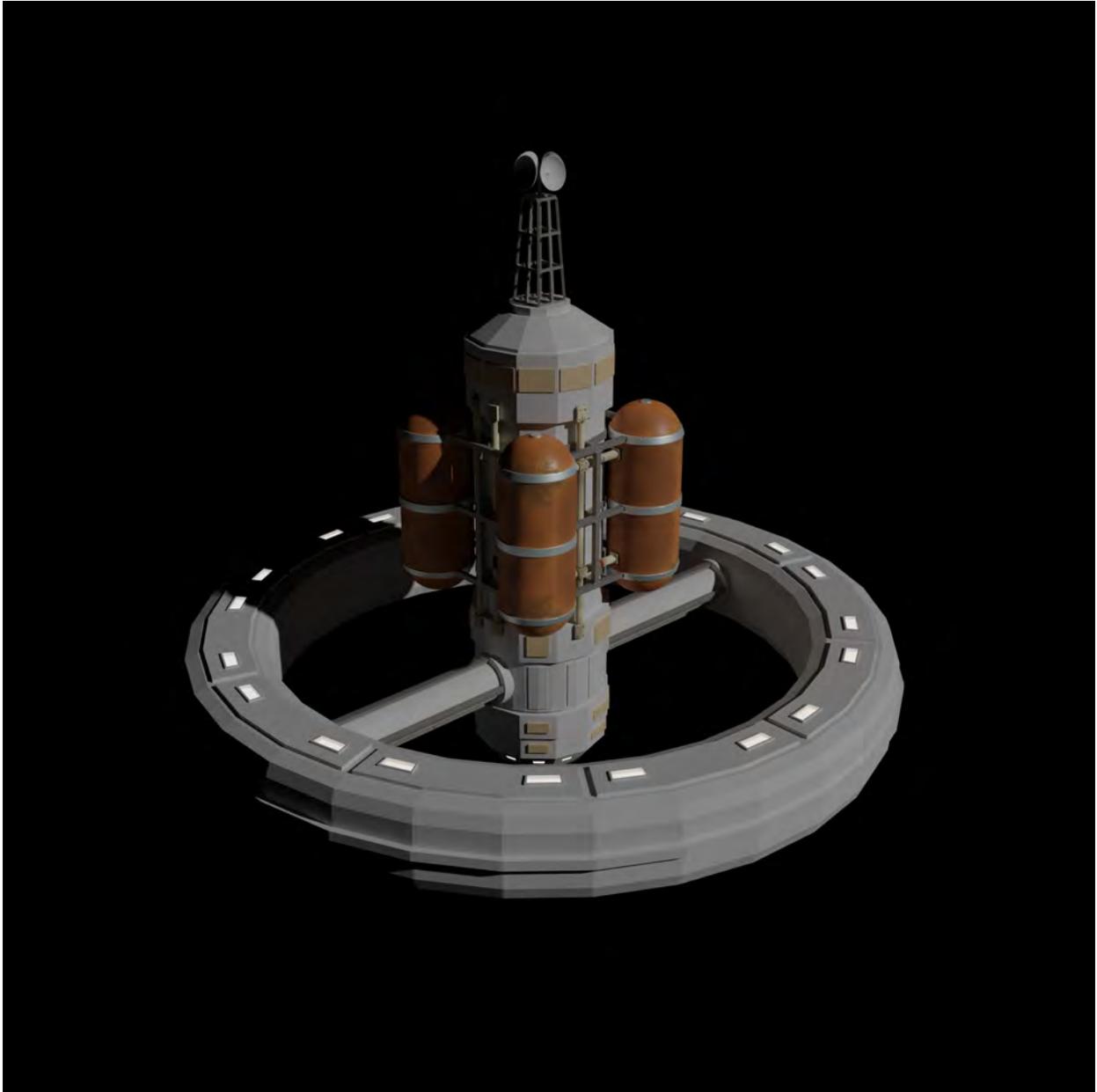
Now that the general structure of the space station is completed, I was able to rig the space station so it could be moved:



The space station can move, rotate, and scale as a whole, and the habitable ring (with its connection to the main body of the station) can rotate along the station's axis.

I continued development on the exterior of the space station in-between other goals in the project. I was able to paint the texture maps for the tanks and tank piping, adding some visual variation to the model as can be seen here:

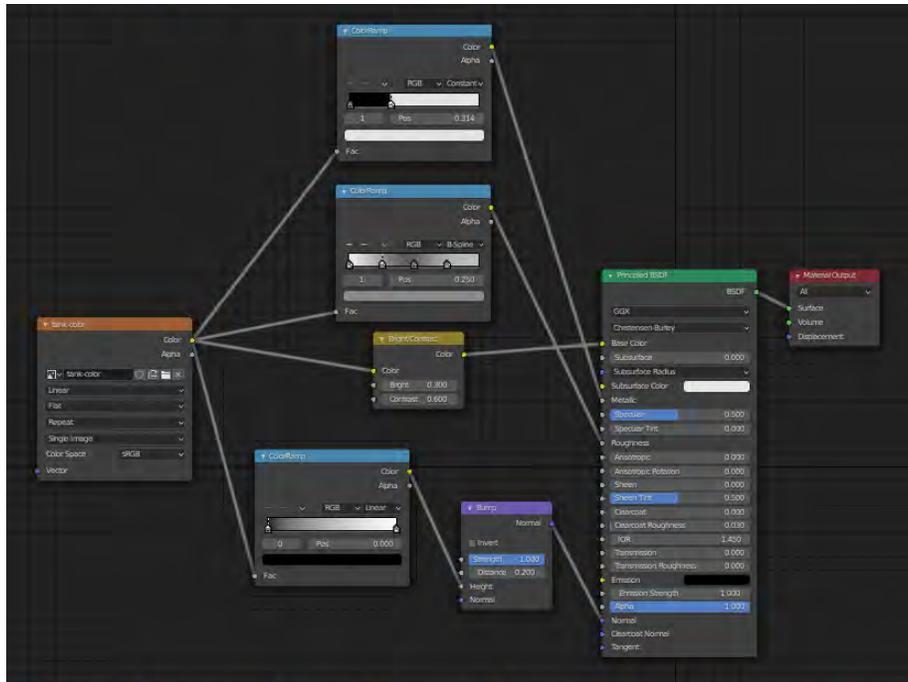




I painted the surfaces using blender's texture painting interface, which allows the artist to paint directly onto the surface like you might paint a physical model. The texture painting tool translates the brush position on the model to the corresponding position on the UV map, which creates the flat texture Blender saves. The flat texture maps for the tanks are shown here:



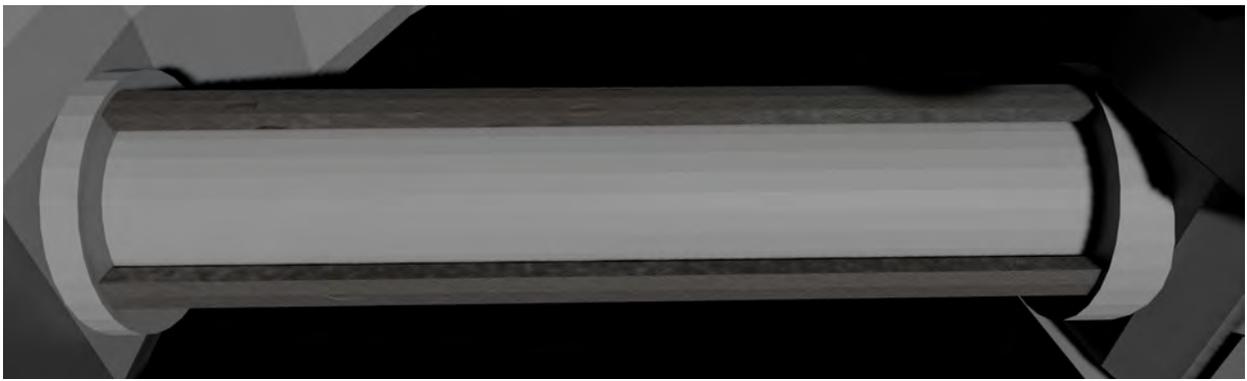
The shader uses this texture file to create the bump map procedurally, with dark regions corresponding to rougher, lower regions on the bump map. You can see how the image texture is used in the shader node setup here:



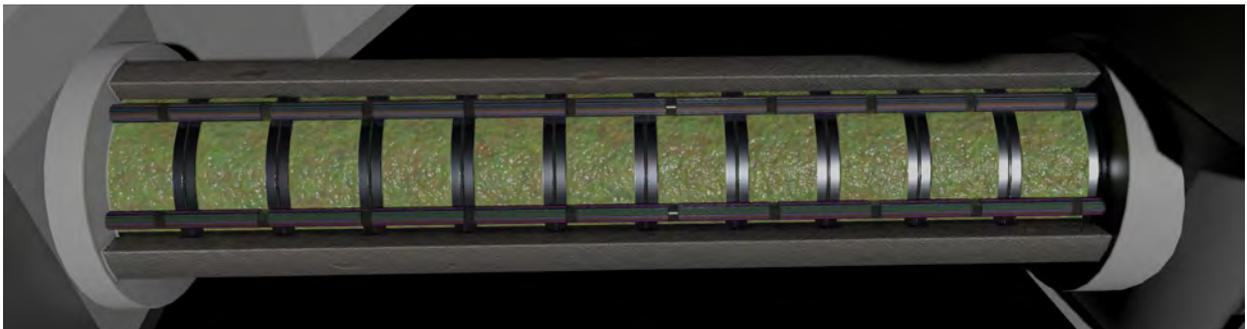
Near the end of the Fall 2020 semester I decided to redo the hab connector bar and the antenna to more closely match my original sketch. With the antenna, I had to completely redo the model of the antenna portion and update the UV. The antenna remains an object separate from the main model, like before, but it is now rigged in the station armature to allow it to turn. The new antenna can be seen here:



Changing the habitat connector was trickier, because it was already UV mapped and I did not want to spend the time to redo the UV map for the entire object. Because of that, I wasn't going to make any changes to the mesh. So to make visual changes to the connector portion, I added mesh objects over the connector which appeared to be part of the model, but were in fact their own parts. Additionally, I used procedural textures to create visual noise which further broke up the original connector. You can see the original piece here:

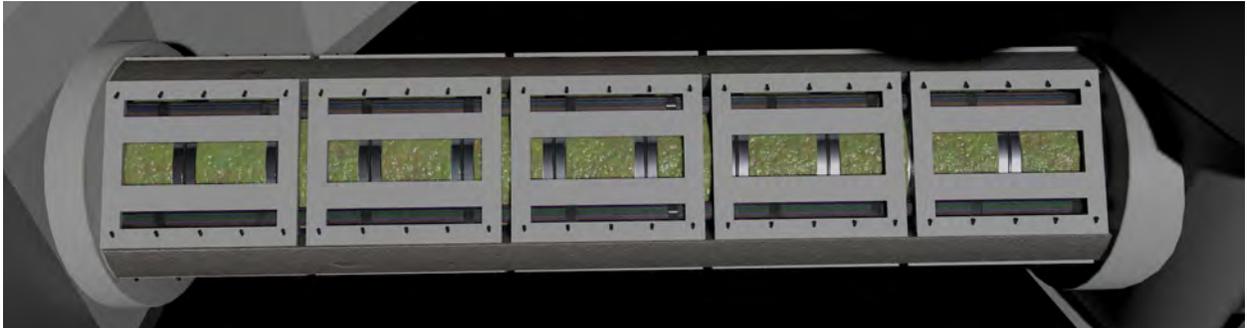


To add visual depth, I created a procedural shader meant to resemble insulation, and added cylinders with a procedural shader meant to look like cable runs, which you can see here:



I then created a panel model which partially covered the connector tube, and added visual depth and some indication to the station's structure with the bolts

'connecting' the panels to the main model. You can see the final version of this here:



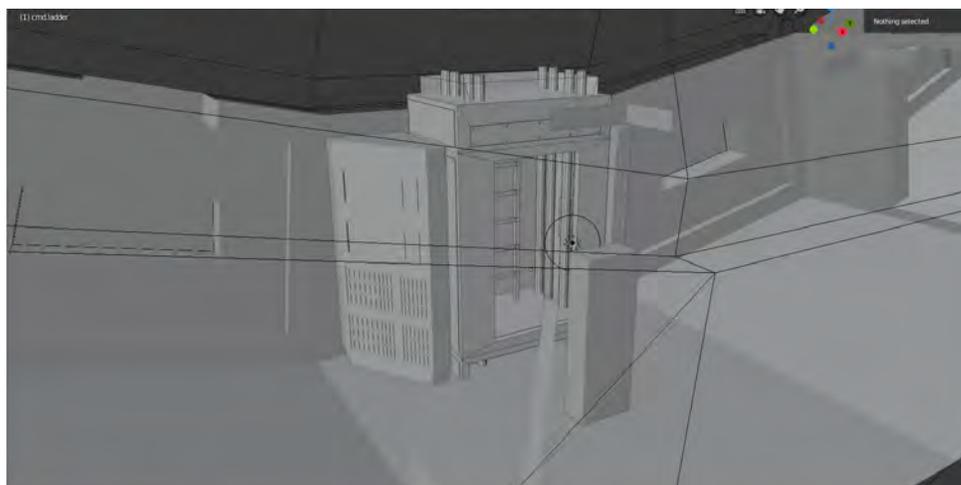
Once exterior of the space station was completed, I was able to move onto the interior assets. It was important to me that the scale of the space station's interior matched the scale of its exterior and could really fit into the exterior model. This is both to give consistency to the world, and to make several shots in the film possible.

To begin with, I took the habitable ring around the space station and created a smaller cylinder with the same number of faces that could fit inside the ring. I then cut walls at intervals of 3 sections, and added windows where they existed in the exterior model. Additionally, lights have been added to the ceiling, and brighter lights have been added into the middle of rooms that are used in the film (this is for presentation purposes only):

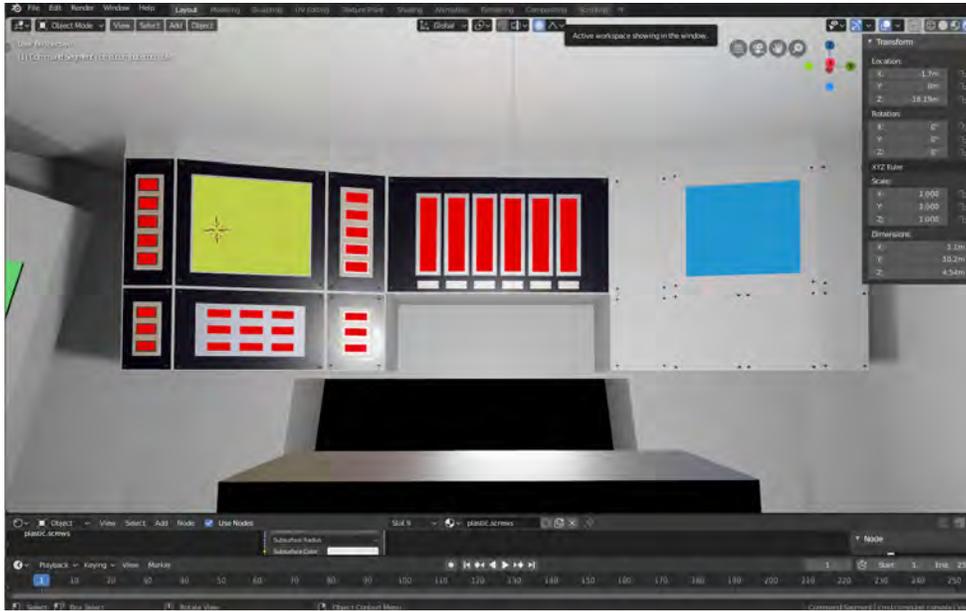


When I created the habitable ring, I specifically created it as a cylinder with 30 sections. This was done to allow for 10 identical rooms which are all 36 degrees displaced from each other. Essentially, what this planning has allowed me to do is when I want to create an object on one section of floor, all I have to do is rotate the entire model by 12 degrees to allow that section of floor to be perfectly flat. This greatly simplifies the modeling process and eliminates errors that can occur if non-even intervals were used.

So now that the structure of the interior is ready, I began developing assets inside the station. This process is the same as the prop development in that I'm first modeling and then shading each model. First I started with the command segment:

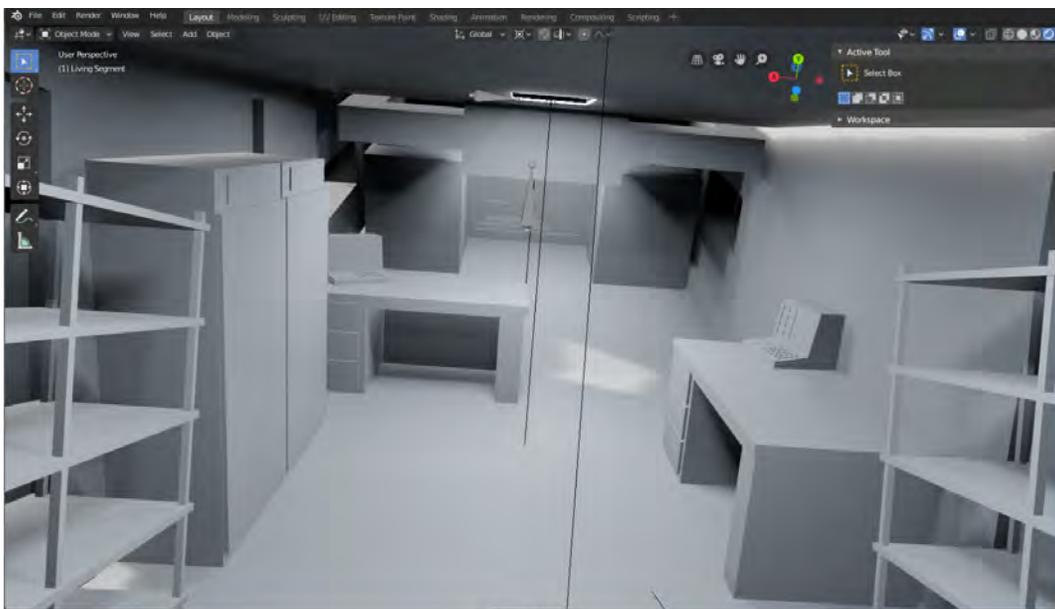






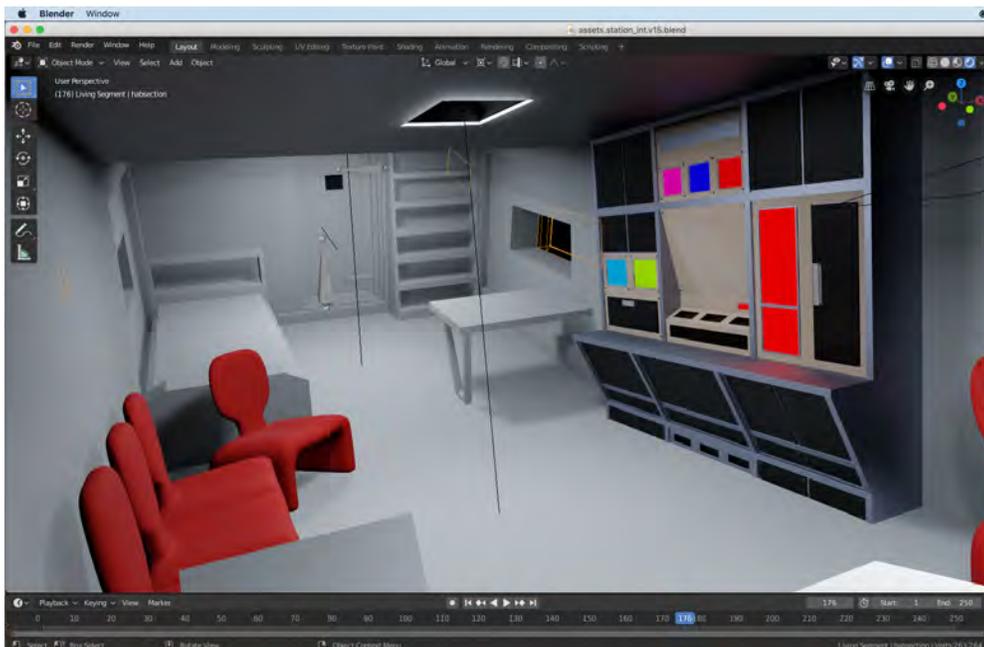
As you can see, I started to do some detail work on the command consoles. I changed my approach after this last version, however, because I realized that in order to get to animating I needed a rough layout of every set, and I could delay detailed work until later. The following screenshots follow this approach. Additionally, for many of these models I'm utilizing placeholder shaders, or no shaders at all (surfaces with matte grey backgrounds have no shaders).

I first did work on the maintenance segment:



During this stage I also added lighting to the “lights” in the ceiling which allowed the rooms to be lit properly. Additionally, lighting from the world’s sun can be seen on floors and other surfaces in the set.

I then moved onto the living segment:

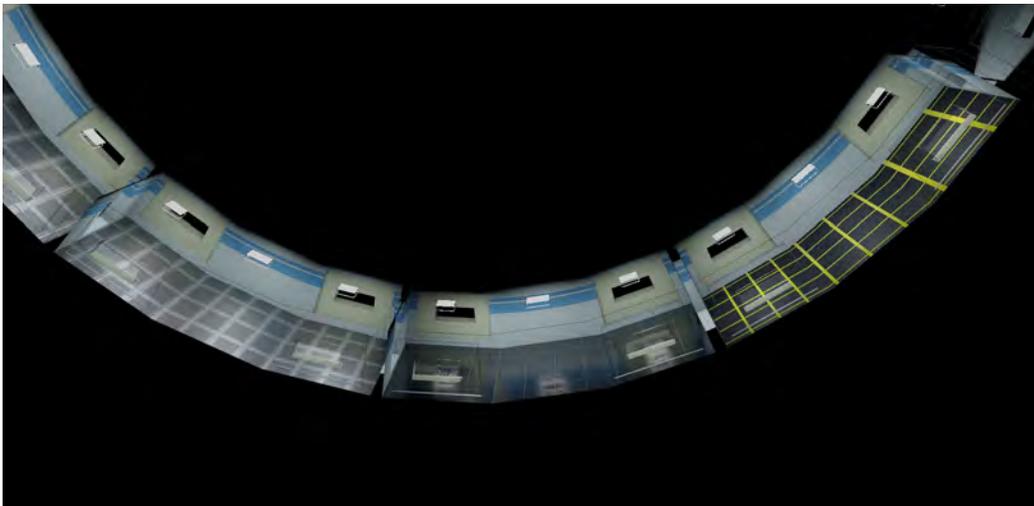


During this phase I added in the door asset discussed earlier, which you can see in the background of the above image.

Finally, I laid out the rough layout of the recreational segment:



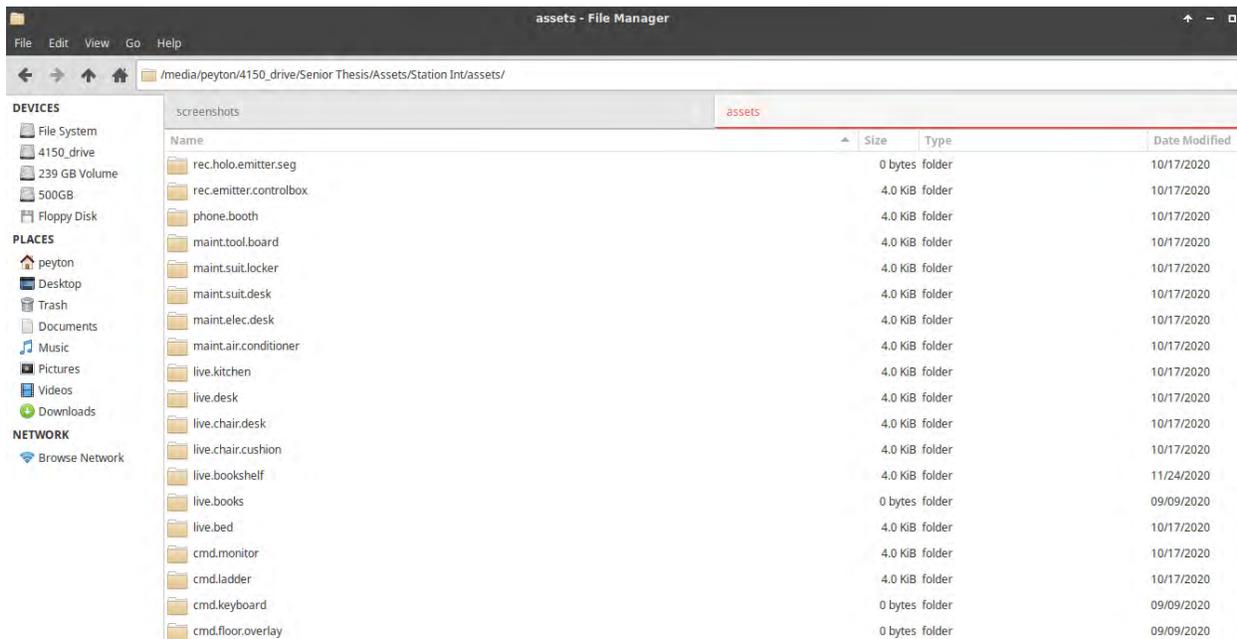
As development continued on the project I focused on refining various components of the interior sets. One majorly important component of every set was the wall and floor surface. I created a single unifying wall shader and 3 floor shaders to surface the set. Each of these are procedural shaders, and can be seen here:



Initially I had created all my assets within the interior set. There were a number of reasons to do this. For one, it ensured that all objects were correctly scaled from the beginning and would fit in the space it needed to fit in. There wouldn't have to be any complicated back and forth on trying to get a linked model to closely match another linked model when each model existed in separate files. Additionally, it made it easier to establish the overall feel of the objects in the scene, and to have a coherency between the different object forms.

Eventually, however, it became increasingly difficult to do detailed model work when the models were in the scene file. There are two main reasons for this. First, most models in the scene were placed on angled portions in the floor, which meant the whole model had to be angled. Blender provides tools that make working with a model like this relatively simple, but despite these tools mistakes and problems still arose. Additionally, as the models got more complicated performance became a greater issue, and small model changes took increasingly large amounts of time.

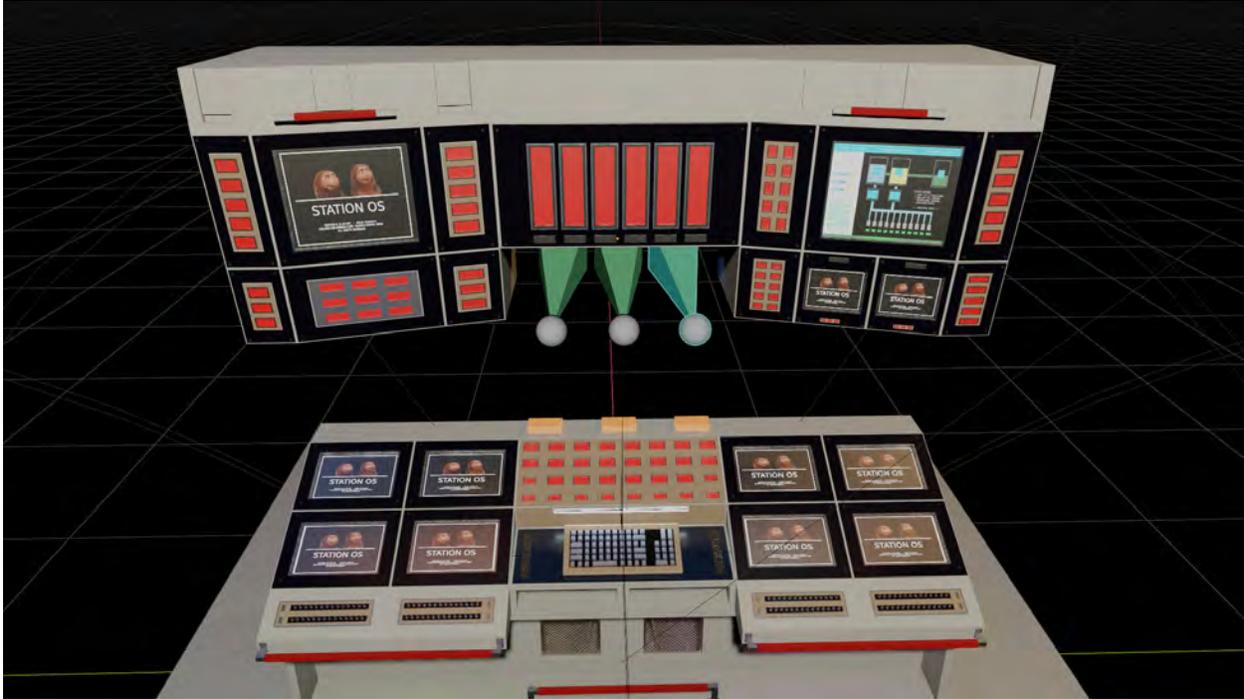
To fix these problems I removed the models from the base set and placed them into an assets directory, which is shown here:



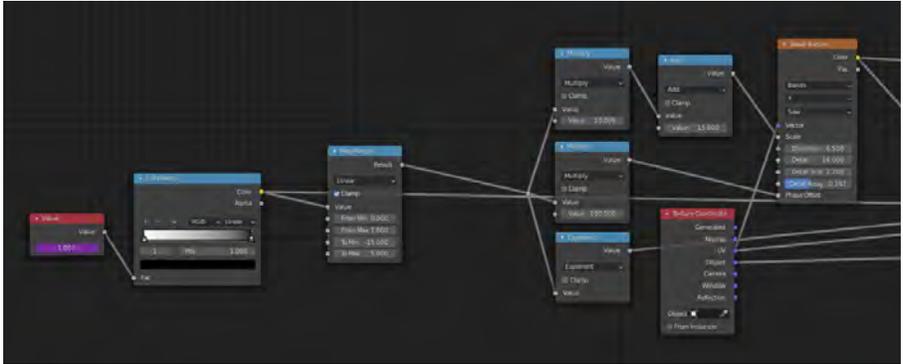
Each asset in the set was placed in its own blender file with its own directory. This simplified my approach in a few different ways. First, it addressed the issues I've already mentioned, as each asset exists in its own file and is placed on a flat surface. Second, assets which required textures or other sub-assets could save those items in their own directory, rather than necessitating a unorganized shared directory. Once I made this change, I was able to make significant progress in the sophistication of the models as shown by this image:



With some objects, as with this computer console, I created python expressions which modified the behavior of the shaders based on a simple armature. For example, with this model, three bones exist which control the displays as shown here:



When all the bones are in the default position, nothing is different. The first bone (on the far left) changes the brightness of the orange “alert” lights, so that an alarm could be animated. The second bone changes the brightness of all lights, including the monitor screens, so that the console could be “turned off” in certain circumstances. The final bone does something more complicated; it introduces a certain degree of distortion into the displayed images as defined by this set of nodes:



The python expression operates on the far left node, and only translates the z-position of the final bone into a value from 0 to 1. The subsequent nodes then mirror this value, so that the top position would yield zero distortion and the bottom would yield 100%, and does some math on it so that the resulting values can be used to drive the distortion of the wave texture, on the far right. When the input

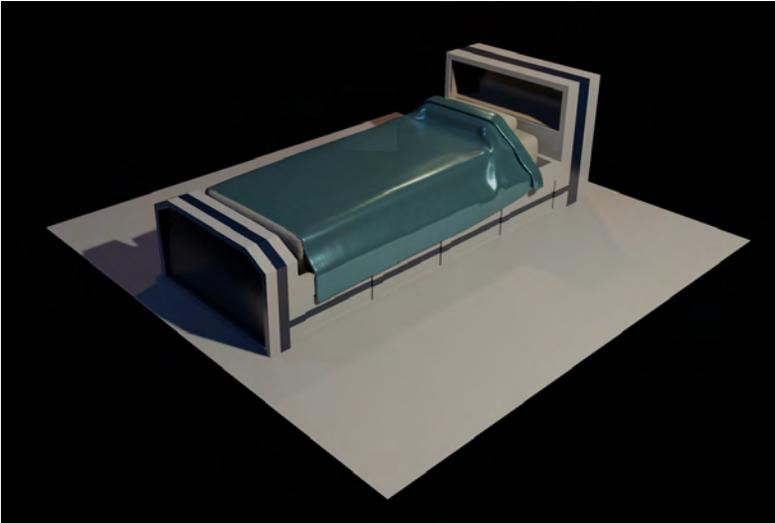
value is 1, the wave texture (which creates a horizontal sawtooth pattern) has no distortion, whereas at 0 the wave texture has a large amount of distortion at small scale. The output of these math and texture nodes is then used to drive a color mix node, which fades between the wave texture and the UV map of the object. The end result of this mixing is the introduction of distortion, as shown here:



As the value drops below 0.5, a curve dictates the extent to which the resulting textures are multiplied by a color noise procedural texture. Once the distortion reaches 100%, very little of the original color is left in the monitors as shown here:

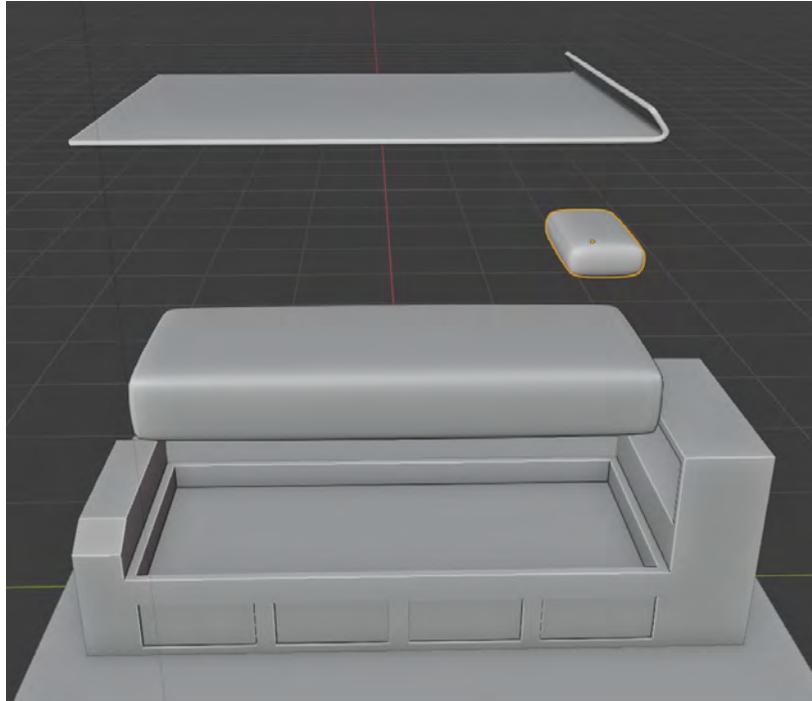


The distortion produced by this shader is not random, and the value of 0.7 on the final bone will result in the same final surface each time. However, when animated properly and combined with animation of the brightness bones, plausible display distortion can be achieved as shown in shot 7 of the demo reel (1:00 - 1:06).



When creating the bed shown above, I had difficulty creating a plausible blanket to overlay the bed from scratch. After an initial attempt modeling the

surface by hand I decided that it would be more efficient and more effective to utilize a cloth simulation to create the blanket model. To create this simulation, I used the bed frame as a static collision object while the mattress, pillow, and blanket were simulated as cloth objects (the pillow and mattress utilized a “pressure” parameter in Blender’s cloth sim, allowing them to maintain their shape). I arranged the objects in the air, as can be seen here:

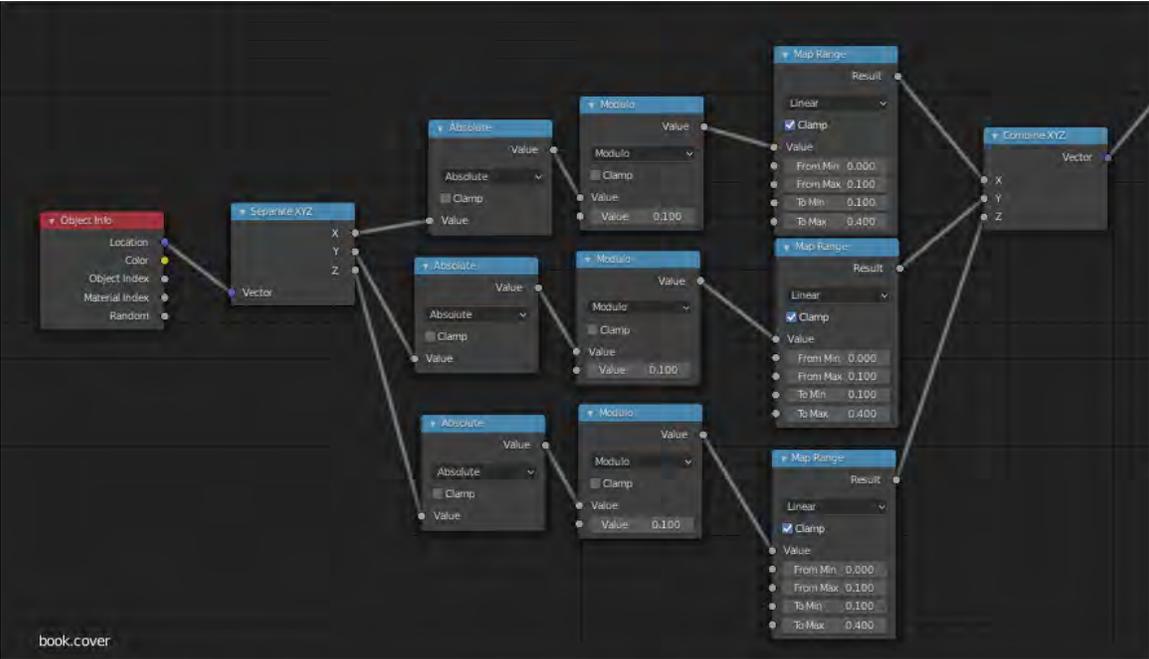


Blender’s cloth simulation handled the rest, and the final model was created by applying the changes to the base model the simulation made. In order to make this work, I had to tweak the position of the pillow and blanket so that the blanket would not slide off the top of the pillow. Additionally, I added the lip over the top of the blanket in the expectation that it would settle to form the kind of “fold-over” common in well-made beds. It made the final result seem more plausible to me.

In addition to these larger assets, I created a number of smaller assets that could be used to create visual complexity and establish the character as thoroughly disorganized. So far, the assets I’ve created are largely meant to exist in the living and command rooms, though by the completion of the project assets will exist for

The image displayed is chosen from a set of ten by taking the absolute value of the X, Y, and Z coordinates of the paper's location in the 3D space, limiting it to a small range of values (in this case, 0 to 0.1), multiplying each by 100, adding them all together, and dividing by 3. The end result of this math is a value from 0 to 9 is chosen based on the object's X-Y-Z coordinate, and this value is used to determine which of 10 images is displayed (0 for the first, 1 for the second, so on). So by moving the piece of paper over very short distances, the artist can completely change what appears on the page without needing 10 different paper assets.

The book shader works similarly, as can be seen by the shader nodes below:



As before, this shader considers the absolute value of the X, Y, and Z coordinates of the book's location. It then restricts the value to a range between 0 and 0.1, which is then translated from that range to the range 0.1-0.4. This value is then directly used as a RGB value, which is multiplied with the book's mottled surface texture to create the final color. Again, as with the paper, this allows the artist to create visual variation without needing many different versions of the same asset.

Animation Reference

Before the animation stage of the project can begin, live action reference footage must be shot. This is done to make the final animation more believable. As in representational approaches to other media such as figure drawing, portraiture, etc., it's always better for the animator to start from real live-action reference footage of whatever movement they're trying to capture. This serves as a base on which the animator can exaggerate and make their characters come to life.

I've already completed approximately half of the reference that I'll need for this project. Screenshots from one of these videos are shown below:



I created a rough version of the space that the shot would take place in, and then acted out the action the character takes in that scene. I can then watch this footage closely and replicate my own movements in the character in the initial blocking passes of each scene. As development continues, I'll begin to exaggerate fine movements that's present in the original reference, and make the animation feel realistic and believable in its own right independent of the reference footage.

Animation

While I was able to get the reference I needed to animate much of the short film, a combination of lack of time and the COVID-19 pandemic really slowed down the progress I was able to make (the lockdown began in the middle of March 2020, about halfway through this thesis project). I have not been able to get most of the animation done for the short film and decided, with some advice from professor Scott Raymond, to focus more exclusively on the asset development. I discovered during the creation of this thesis that the environmental design and asset development elements came easier to me than the animation did. That's partially due to lack of recent practice with animation, but I think it's also got to do with the fact that I find environments and settings more interesting than character animation. So in the Spring, Summer, and Fall of 2020 I directed my attention to those assets rather than developing the animation.

That's not universally true, however. I did animate shot 11 of the storyboard. I did this because I wanted to use it to feature how the environment would work in the story that I had created. Additionally, the zero-gravity environment in that shot posed an interesting challenge, so I decided to focus on that shot in the development of my demo reel. You can see a portion of this shot in the linked demo reel (1:16 - 1:24).

Summary of Experience

It's extremely weird to be summarizing the experience of working on a project for almost 18 months into a single page. It's made even weirder when you consider the larger context this project was completed in. In January, just 5 months into the project, the COVID-19 pandemic began in China and 2020 began in earnest. Of course by March the whole world would be locked down, and things only got weirder from there. The whole reality of how school worked changed completely. Most of the first 7 months of this project was done in the company of friends and colleagues, in the highly motivated crunch environment that late nights in the Animation Lab provide. After March, the project was done in quiet solitude, removed from the environment that had fueled most of my progress up to that point.

It's ironic, looking back, how the story I wrote for this thesis reflected the reality we'd all soon be living. The Station Keeper was envisioned as a version of myself at the start of college: alone and in an alien environment, longing for a past that no longer existed. So imagine my surprise when that transition came again, the world shut down and the social life we once had came to an end.

In some ways, the lockdown really hindered my development on this project. But, at the same time, working in the lockdown helped me realize a number of things about myself personally and professionally. I'll share some of these lessons with you, though I think the only truly effective way to learn them is to go through this process yourself.

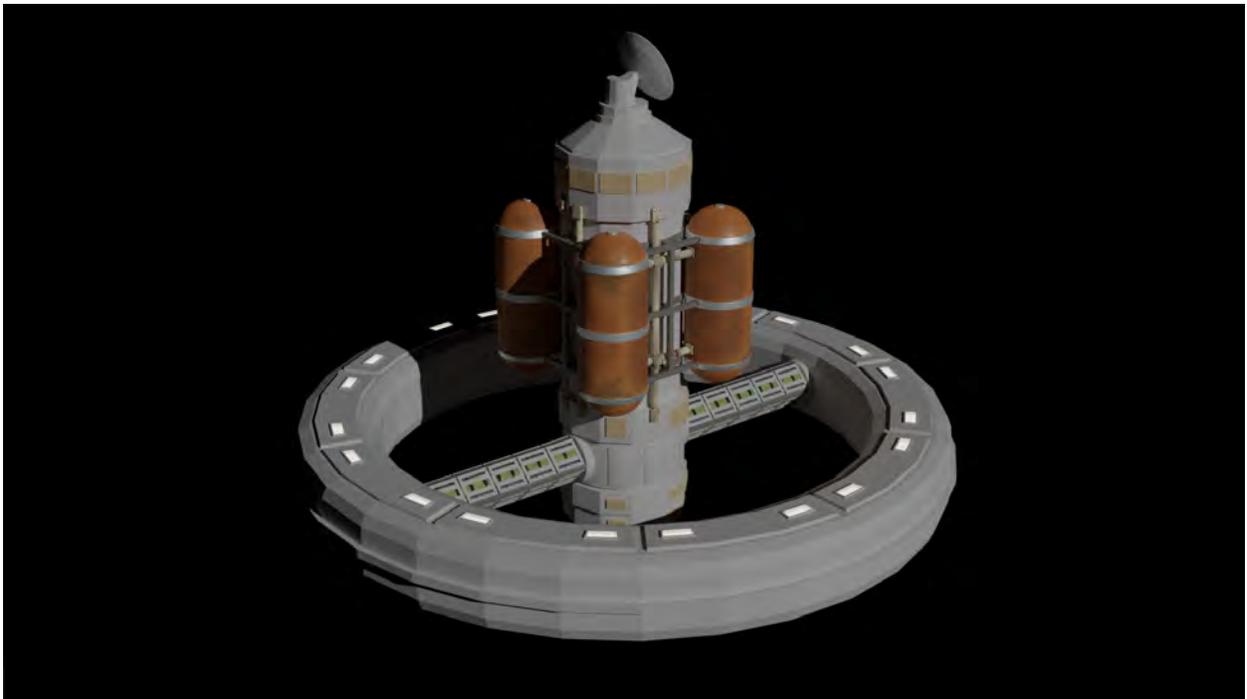
First, it's extremely important to recognize your limitations while also dreaming and pushing beyond them. Your dreams should be broad and big and wondrous, but you've also got to learn how to focus them into achievable goals. And, particularly important for me, you've got to learn not to criticize yourself unreasonably in that focusing process. Everyone has limitations, it doesn't make you any lesser a person to admit that.

Second, nothing is more important than your personal health. If you have to scale down your project in order to stay mentally or physically healthy then you have to scale it down. Again, it is good to push your limitations, but if you push yourself too hard you risk physical and mental injury, which can take a lot longer to heal than the time it takes to take a genuine break every now and then.

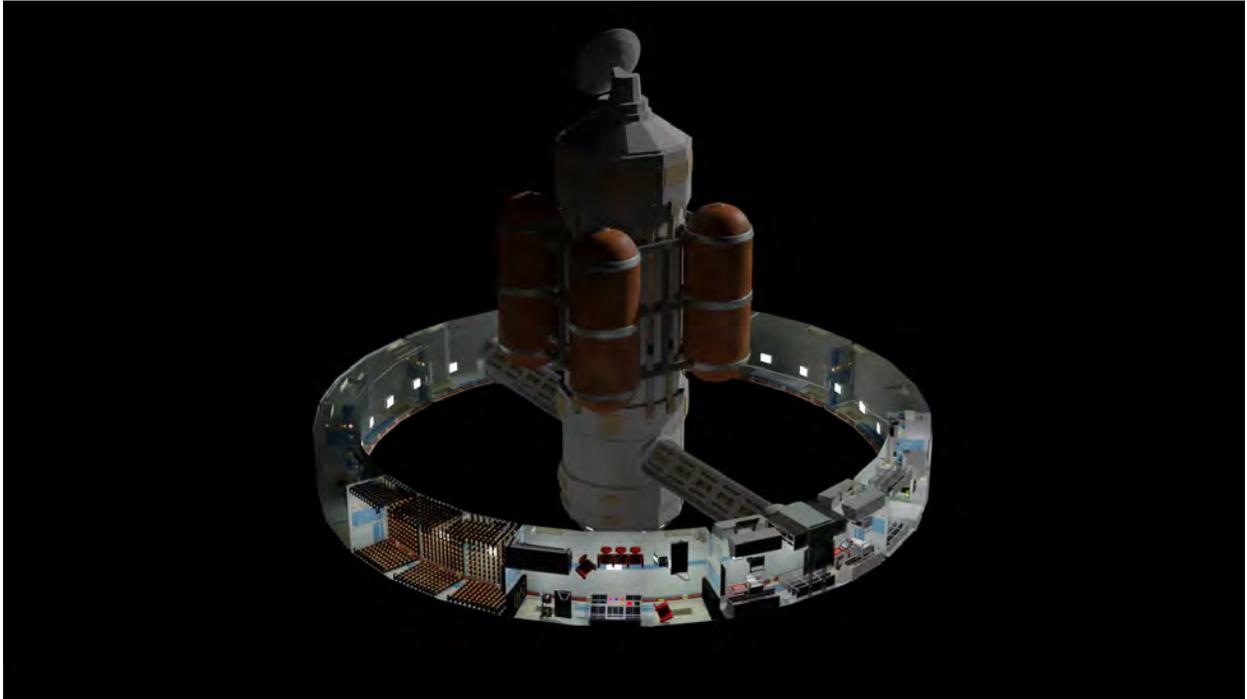
Final Product & Future Development

The following images depict the different environments and assets created for this thesis. While they are final for the purposes of this project, I intend to continue developing the assets I've created and, with the help of friends, eventually realize the short film I had set out to create nearly 18 months ago. If you're interested in following the development of this project going forward, I'll be posting my work as it develops on my personal website (pvanhook208.wixsite.com/site).

Station Exterior:



Station Interior Cutaway:



Station Command Room:



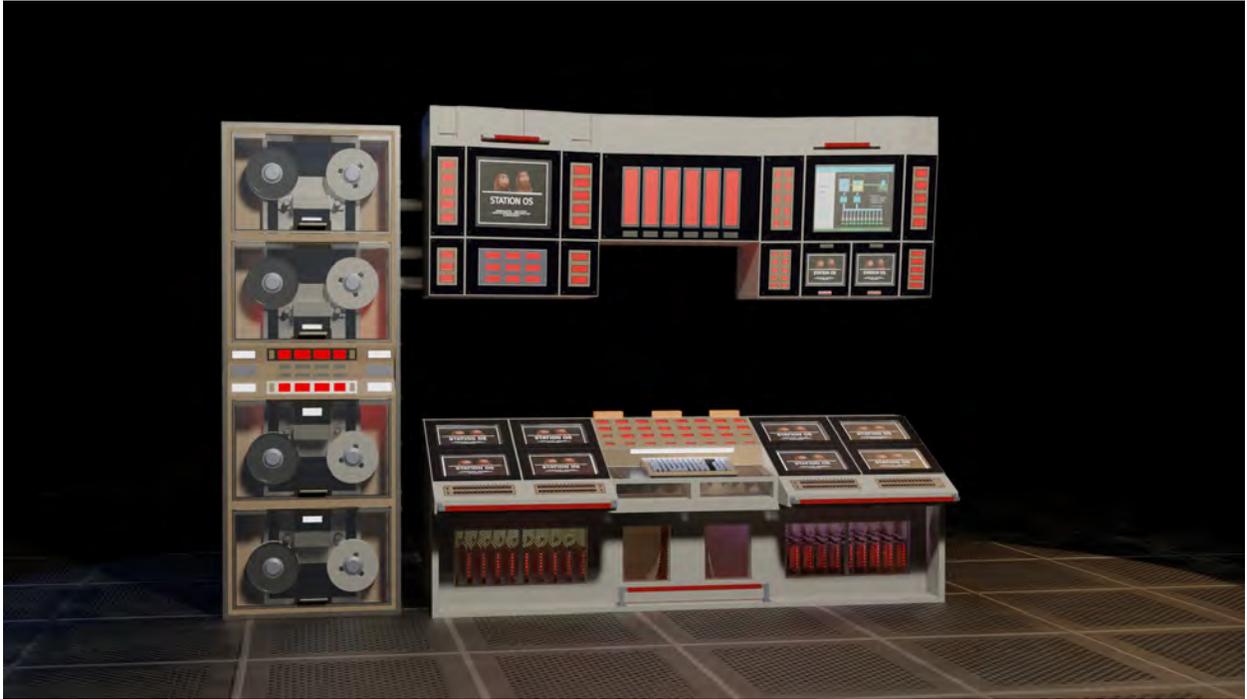
Station Living Room:



Living Area Props:



Command Console Prop:



Shot 11 Animation Still:

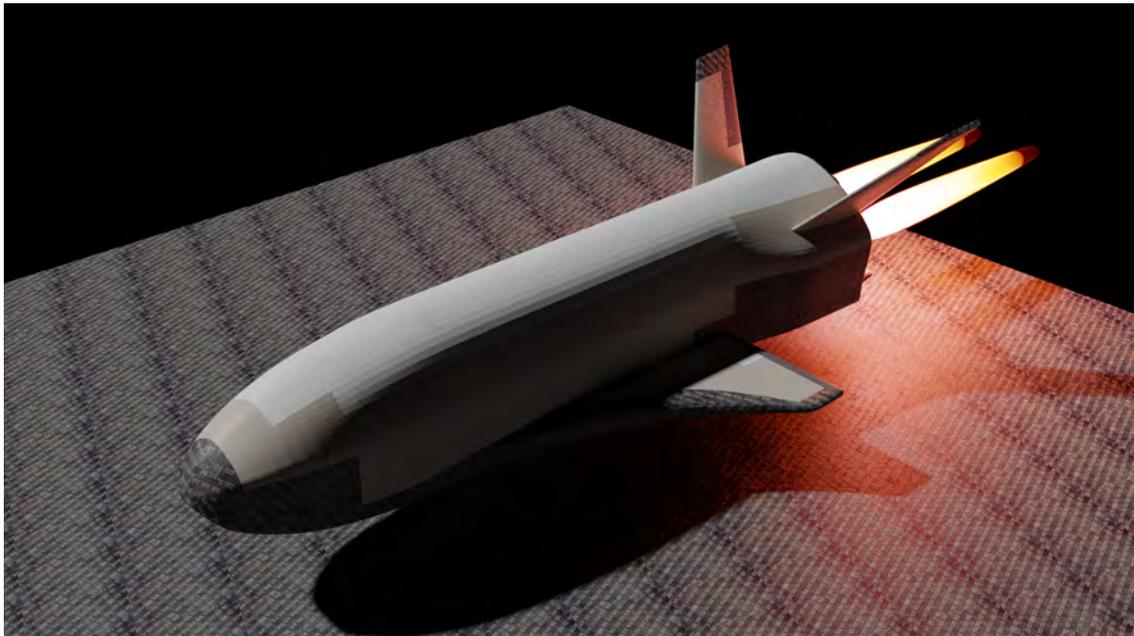


Character Test Poses:





Shuttle Prop:



Station Floating in Space:



Credits:

The Ivan character model was created by Nikolai Mamashev and distributed for free at the following link:

<https://www.blendernation.com/2016/07/13/model-download-ivan/>

I'm incredibly thankful to the artist for providing this asset for free.

Textures used for the Earth and Moon in the title and closing shots of the demo reel were sourced from NASA's "visible earth" catalogue. The textures can be found at the following link:

<https://visibleearth.nasa.gov/collection/1484/blue-marble>

Textures used for the Moon were sourced from NASA's Scientific Visualization Studio, and those textures can be found here:

<https://svs.gsfc.nasa.gov/4720>

Additionally, I would like to express my endless gratitude for Scott Raymond, Heather Abels, Paul Collins, and McLean Fahnstock for their advice and support during the development of this project.