File Hierarchy CAD Model Navigation for NASA JPL Ops Lab's Protospace

Team Ada Lovelace

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1. Team Page

Albert Pulido (Project Manager)

Albert Pulido has a background in storytelling, public policy, design, and project management. His poetry and short stories have been published at a number of venues, including *No, Dear* and *PusanBridge*. He currently works in the NYC Mayor’s Office for the Deputy Mayor for Strategic Policy Initiatives leading technology and data initiatives in Mental Health and Pre-K for All.

Albert has a BA from Cornell University and an MFA from the University of Iowa Writers’ Workshop.

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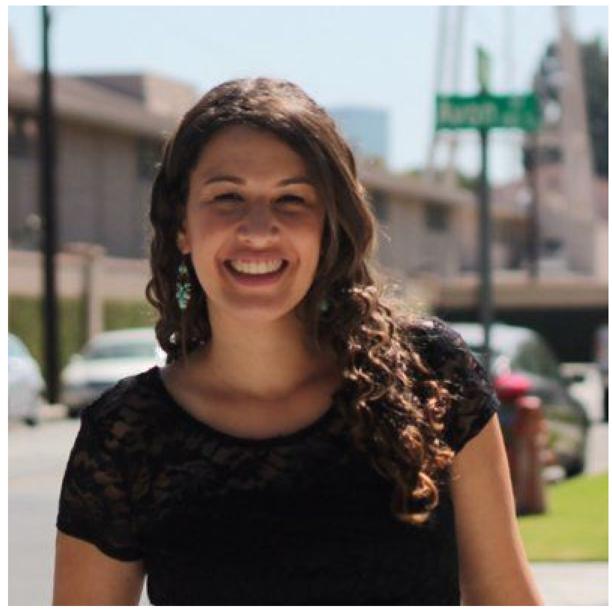
Tatiana Pilon



Tatiana Pilon is a research and development engineer exploring the intersection of art and engineering. She is currently pursuing her master's in Integrated Digital Media at the New York University School of Engineering where she creates emerging technology experiences using virtual reality and augmented reality as well as developing groundbreaking media and entertainment opportunities.
She is passionate about innovation for social good alongside entrepreneurship.

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Melody Loveless	Bryce Summers
	
Melody Loveless is a creative technologist, musician, and educator. She currently works for Tech Kids Unlimited, a non-profit dedicated to teaching technology to children with special needs, as a counselor and tech master. She holds a MM in Music Composition and Theory from New York University and is currently pursuing a MS in Integrated Digital Media at New York University. melodyloveless@gmail.com	Bryce Summers is a computer scientist and new media artist who invents media objects, such as interactive tools, games, and new algorithms that communicate abstract ideas to people. He has a BS in Computer Science along with a minor in Bassoon playing from Carnegie Mellon University and is currently pursuing his research while a masters student in the Integrated Digital Media Program at New York University. bs3363@nyu.edu

Alexa

Alexa Shea is interested in taking things apart to find out how and why things work, and how to make them work better. She is studying multiple languages, both natural and computer, in an ongoing endeavor to understand everything she reads. She is not quite there yet.

Alexa Shea is currently pursuing a combined BS and MS in Computer Science at the NYU Tandon School of Engineering.

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Abhinav Jha

Abhinav is a Masters student at NYU working his way towards completing his degree in Cyber Security. He has a couple of years of experience working in the Security domain at Cisco and now aims to gain some expertise in the field. He is passionate about all things tech and now wants to try his hand at UX Design for fun.

When not studying, he enjoys playing soccer and table tennis and is a devout Liverpool FC fan.

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2. Project Overview

Introduction

The task was to design and communicate new features for mechanical engineers at NASA's Jet Propulsion Lab (JPL) that would allow them to elegantly navigate a file hierarchy of spacecraft parts in the augmented reality application, Protospace. Additional desired features were: highlighting parts, grouping, hiding, picking parts from different hierarchical branches, and jumping around hierarchies.

Our team approached this with an Agile design methodology by:

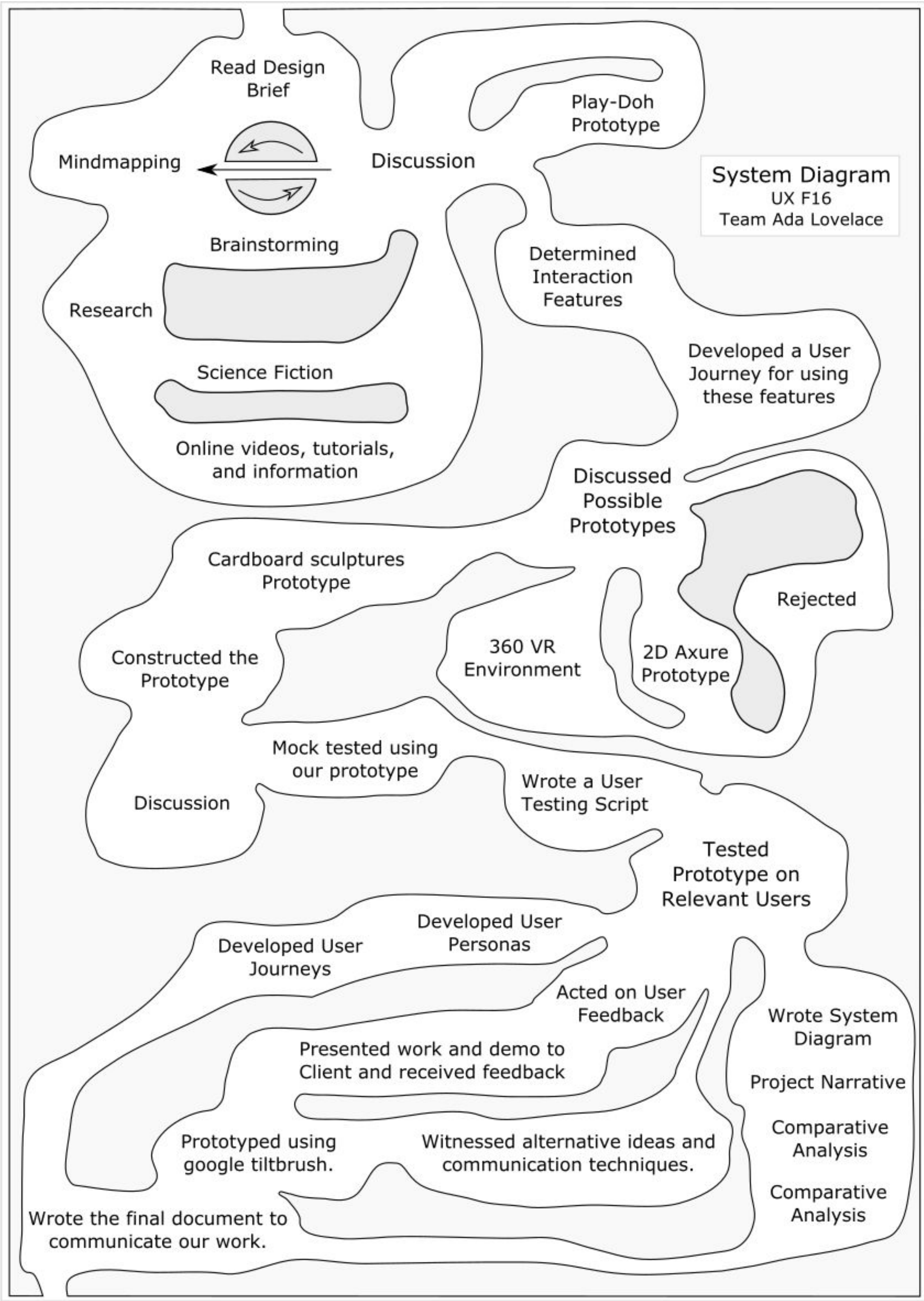
1. Ideating, and blending research with brainstorming techniques, like mind maps,
2. Developing sketches of our concepts,
3. Interrogating the logic of our sketches with User Journeys and Personas,
4. Further ideating to integrate desired features and lessons learned,
5. Physical prototyping & User Testing, and
6. Iterating on our prototype.

During the first stage of the project, the team met as a whole met twice weekly to collaboratively work on deliverables. Each team member selected the deliverable they would be responsible for. The majority of time was spent researching and developing the ideas and logic using the methodology outlined above.

The second stage of our project involved building the physical prototype and testing it with users. We decided on building a physical prototype, rather work with a clickable Axure prototype, to recreate the experience of augmented reality with the Hololens, and to allow the user to maneuver the tool in physical space. A physical prototype was also the best solution because we could use team members as mechanical turks to power the interactions.

After receiving feedback from user testing and iterating on our prototype, we presented a prototype to staffers from JPL. They provided further feedback, which we incorporated into our final prototype, and communication tool. We built our final prototype in Google Tilt Brush, the Virtual Reality drawing application, using the HTC Vive.

3. System Diagram and Narrative



4. Discovery Process

Introduction

The discovery process was comprised of testing the hololens, collaborative concept-mapping, researching, sketching, and developing early user journeys. The desired-feature list provided in the project briefing was our brainstorming guide, which is the following:

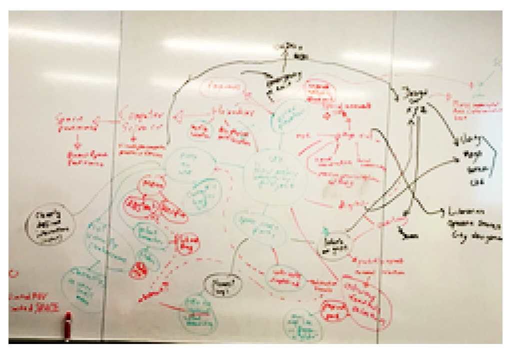
- Navigating through parts hierarchies,
- highlighting parts,
- grouping,
- hiding,
- picking parts from different hierarchical branches,
- and jumping around hierarchies.

The team developed mind maps and researched each of the above features. We discussed all of the ideas produced from the brainstorming and research and integrated them into sketches.

Discovery Process Overview

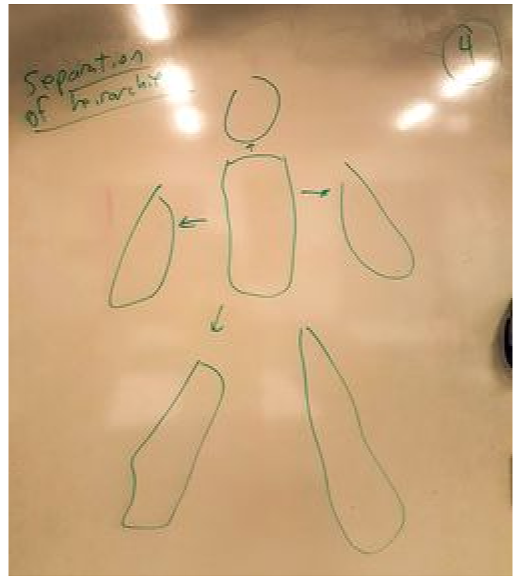
1. Mind Mapping

Team members collaboratively developed ideas for features.



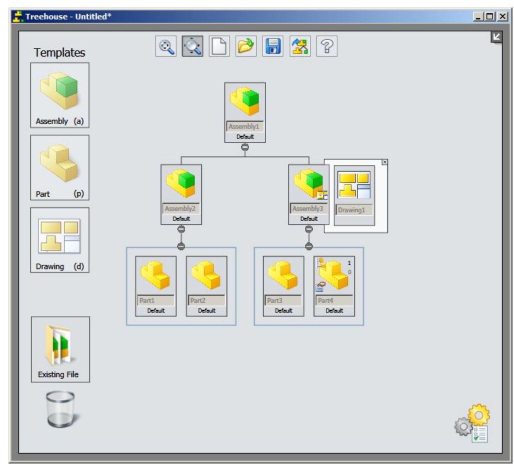
2. Sketching

Team members sketched out feature ideas. Pictured: an early iteration of the "Exploded view," that is present in the final prototype.



3. Research & Comparative Analysis

Team members researched products that offered comparative solutions. Pictured at right, a still from the the software application, 3D Solidworks, that inspired the final prototype.



5 & 6. Comparative and Heuristic Analysis

A comparative analysis was prepared to learn from similar tools, and gain design inspiration for how similar problems we were facing were tackled.

Comparative Analysis: Hierarchy Component

	Solidworks	**CAD**	**Project Esper (3D 4 Medical)**	**Unity**
Description	CAD Model Software	2D and 3D Design Software	Mixed Reality healthcare application	Game Engine
Navigation	2D or 3D User Navigation	2D or 3D User Navigation	Mixed Reality 3D Navigation	2D or 3D User Navigation
Features	The software allows users to create, manipulate, manage and preview projects in 2D and 3D environments	The software allows users to design, inspect and manage engineering projects with 2D vector-based graphics and 3D modeling of solid surfaces	The application allows medical learning through anatomic animated models	The cross-platform allows users to develop video games, VR and AR experiences for PC, consoles, mobile devices & websites
Hierarchy	Three level structure with parent-child relationship between the folders	The 2D CAD hierarchy navigation is based on a tree level structure where each level control has subordinate levels and tag numbering on each item	Augmented reality navigation throughout the human body parts using haptics movement	The software displays a complete list of objects in the scene where each object can be grouped in a parent-child object relationship
Virtual UI	No	No	Yes	No
Visual Feedback	2D cursor and windows	2D cursor and windows	Virtual Panels	2D cursor and windows
Haptics	No	No	No	No
Target User	Engineers and	Architects,	Healthcare	Game Developers

	Designers	Designers and Mechanical, Electrical & Civil Engineers	Professionals and Students	and Emerging Technology Content Creators,
Opportunity	Our target audience is familiar with the CAD navigation structure	Our target audience is familiar with the CAD navigation structure	Augmented Reality immersive navigation through animated models	The 3D object hierarchy list enables the user to clearly identify and manipulate an object among multiple objects in a scene
Relevancy	Clear UI navigation and intuitive tree structure file hierarchy	Most of the 3D CAD programs let the users rotate objects in three dimensions	Haptics movements allow users to navigate through the file hierarchy in augmented reality	3D Object parent-child file grouping allows the user to visualize the object properties and subcategories
Inspirational Relevancy	10	8	9	5
Visuals				

*Scale 1-10(highest score)

Comparative Analysis: Input Devices

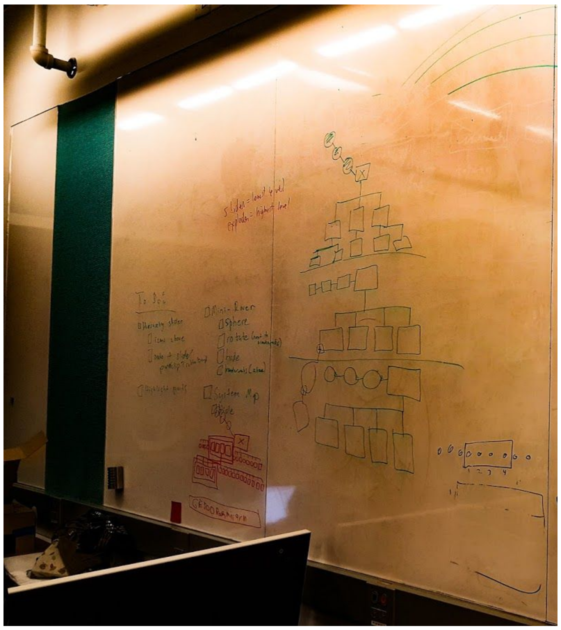
	HTC Vive Google Tilt Brush	**HoloLens Japan Airlines**	**Augmented Reality for Task Localization in Maintenance and Repair (ARMAR)**	**HoloLens A New Morning Magic Leap and**
Description	Virtual Reality three-dimensional painting application	Mixed Reality Training System	Augmented Reality overlaid for execution of procedural tasks in maintenance and repair domain.	Mixed Reality Overlaid Panel control
Navigation	Virtual Reality 3D Navigation	Mixed Reality 3D System	Augmented Reality 3D Task Management Panel	Augmented Reality 3D Productivity Panel
Features	The Virtual Reality application that allows the user to paint using the HTC Vive controllers while immersed in a 3D space. The user can create, share and archive his/her three-dimensional virtual artwork	The Mixed Reality application enables a realistic cockpit environment experience in order to train flight crew trainees. As well as a realistic engine environment where engine mechanics can study aircraft systems	The application determines how real time computer graphics overlaid on the actual repaired equipment, can improve the productivity, accuracy, and safety of maintenance personnel.	The Augmented Reality experience overlays a productivity panel over the user FOV
Hierarchy	The user navigates the cubic interface in order to explores the hierarchy options	Overlaid augmented reality panel control and voice guidance navigation	Overlaid augmented reality panel control with tool labels for the physical tools	Overlaid augmented reality productivity panel control
Virtual UI	Yes	Yes	Yes	Yes
Visual Feedback	Virtual Cubic Panoramic Panels	Virtual Panel Control	Virtual Panel Control	Overlaid Data Screens

Haptics	No	No	Yes	No
Target User	Virtual Reality enthusiasts, Designers and Artists	Engine mechanics and flight crew trainees	Military Mechanics	Mixed Reality enthusiasts
Opportunity	The user can create, walk around and share his/her 3D virtual artwork	The user can learn engine systems and cockpit instrumentation panels with a hands-on experience	The user can explore the interactions between physical and virtual world while performing a task	The user can perform office tasks without his/her personal computer
Relevancy	Intuitive UI navigation and intuitive cubic hierarchy structure	Overlaid Intuitive UI with voice guidance navigation option	Easy to manipulate 3D virtual buttons and labels	Clear UI and intuitive overlaid data screens structure
Inspirational Relevancy	9	8	5	7
Visuals				

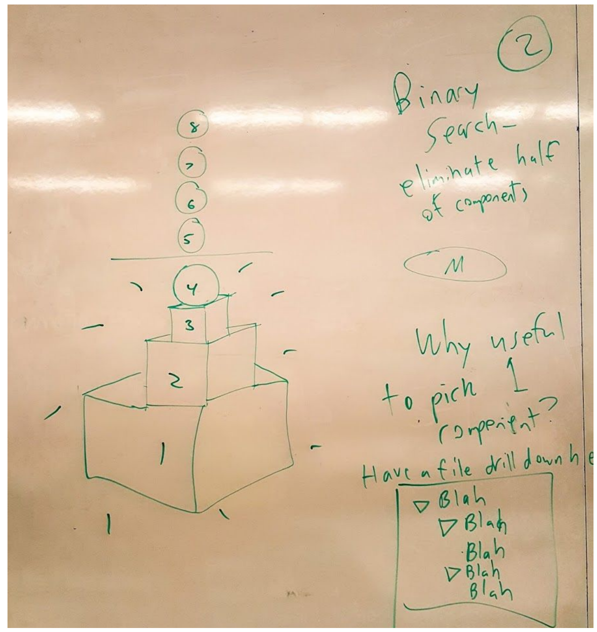
*Scale 1-10(highest score)

7. Sketches

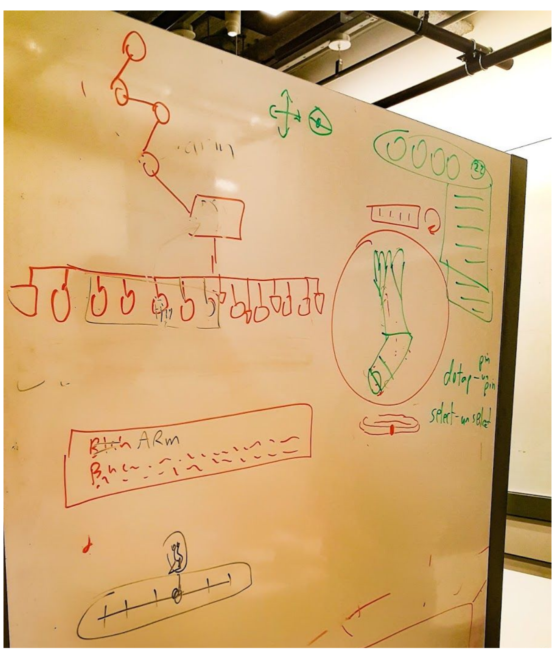
Below are sketches for features.



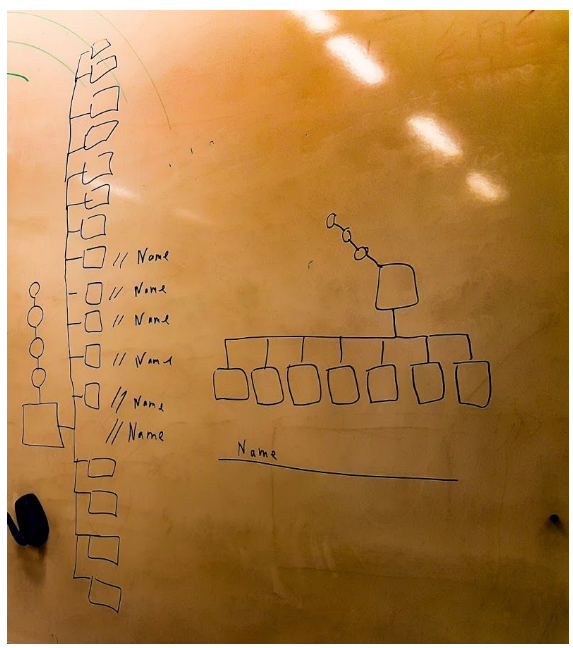
Several NavTree designs.



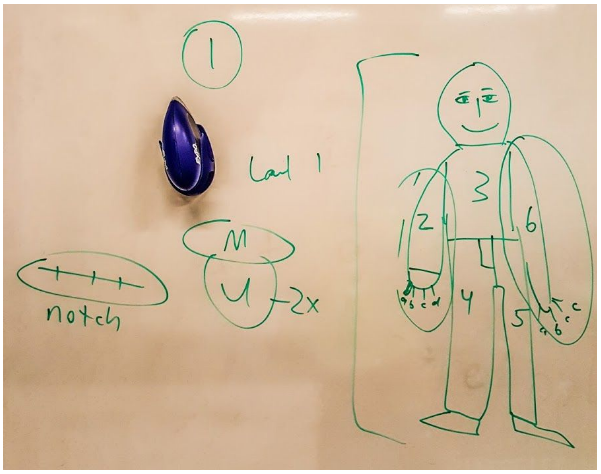
Sketch of binary search interaction.



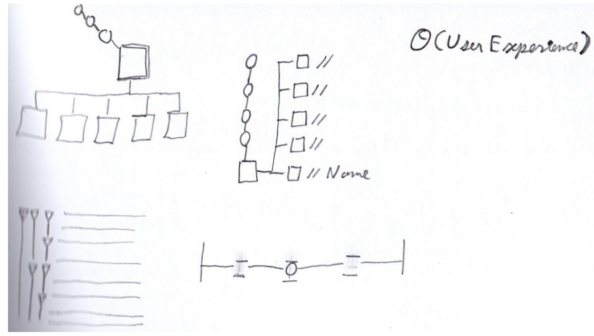
Clockwise from top: Sketch of NavTree, Explosphere, Hierarchy Slider, and Label.



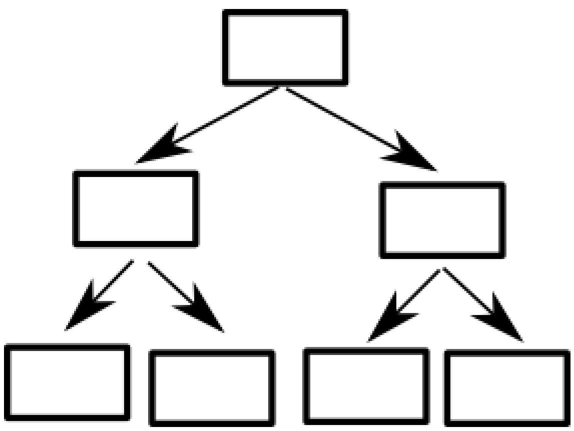
Horizontal Layout NavTree layout (left) and balanced vertical singleton layer NavTree with breadcrumbs (right).



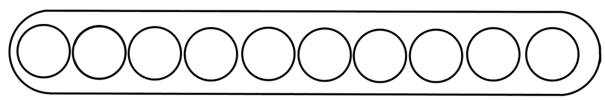
Concept sketch for the Hierarchy slider



Paper Sketches clockwise from top: NavTree, Horizontal NavTree with name spaces, Traditional file structure hierarchy.



Line drawing of naive NavTree.



Line Drawing of GUI bar.

8. User Personas

Introduction

In order to interrogate the logic of our user flows, the team developed user personas that aligned with the target users: Mechanical Engineers at NASA JPL. The team also developed User Journeys that aligned with the types of task our target users would use.

User Personas

Darick

Education:

B.S. in mechanical engineering from the University of Illinois at Urbana-Champaign

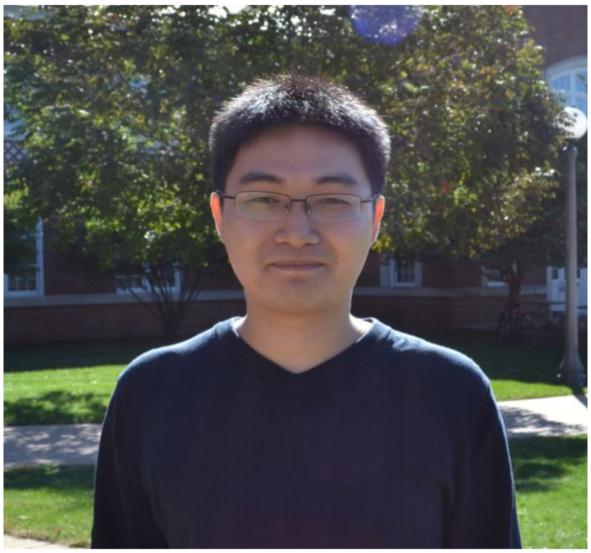
Career:
Interned for 5 summers at the Goddard Space Flight Center. Immediately started working as a mechanical engineer at the NASA JPL after graduating from college.

Darick lives by himself and has no romantic relationships at the moment. He spends most of his time thinking about his work.

Darick really likes structures and he conceptualizes the 3D models he uses as a series of substructures nested within each other. He is used to using programs such as Solidworks that include a parts tree for navigating his models. While in school Darick took some computer science classes and he tends view the world more rationally than empirically. He really likes robots.

Darick hasn't had too many experiences with virtual reality, but he does own a google cardboard device that he uses in his spare time.

Patrick



Education:

B.S. in Mechanical Engineering and M.S. in Mechanical and Aerospace Engineering from George Washington University.

Career:

Hired straight out of college, Patrick is a Thermal Engineer at NASA JPL. Before graduation, he interned with Aerospace Lab at NASA.

Patrick is pretty comfortable with VR/AR apps having been exposed latest technologies while at school. He likes to play VR games and is a big fan of Supershot VR, a virtual reality FPS game that he used to play with his friends using Oculus Rift in the Games Lab. Due to his stint at NASA, he was called "Lunar Man" by his closest friends.

He likes to look at specific parts related to his project directly on the big rover and is comfortable with the navigation. He has mastered using the Hololens technology very quickly as compared to his teammates.

Samantha

Education:

B.S. in Mechanical Engineering from Ohio State University.

Career:

Samantha is a senior in college who is currently a Mechanical Engineering Intern at NASA JPL.

Samantha has to work quickly and efficiently, and is more familiar with where the parts of the rover are in space than in the hierarchy. She prefers using the big rover model for large and visible pieces and the small "exploding" rover model for smaller or hidden pieces.

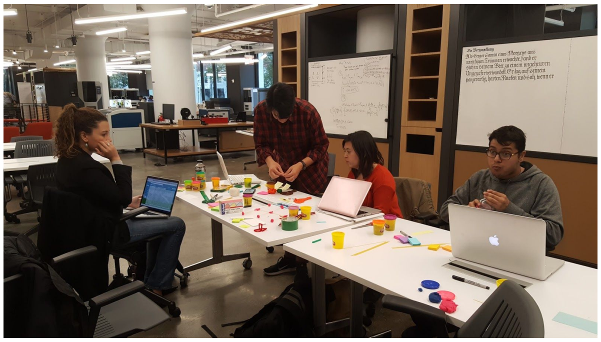
9. Prototypes

Introduction

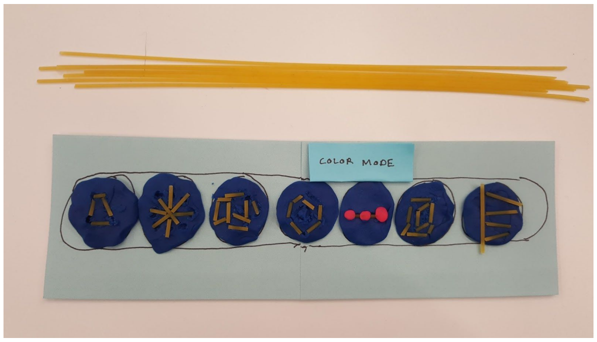
Over the course of the project, from brainstorming, to sketching, to research, the team developed a number of prototypes to test ideas with team members, the UX class, and user testers. The first iteration was done in play-doh to test the hierarchy slider, which the team devised to meet the requirements of the use-case provided in the brief: to select a whole robot arm. After receiving feedback from the class, and from the class's UX consultant, Eric, the second prototype was developed in paper, incorporating a new feature: the hierarchy tree, which was originally conceived to be an entire hierarchy tree of the rover's parts, displayed at all times. When presented to the UX class again, we received feedback, which we incorporated into our next prototype, developed in cardboard. For this prototype, to further highlight a selected item, we developed the "mini-rover" or exploded view, which displayed an exploded view of a selected object. We formally tested this prototype with users, and presented it to class and to NASA representatives. From the feedback we received, this led us to develop our next prototype in Google Tilt Brush. Rather than invest time in developing new cardboard models, which is extremely time consuming, we quickly developed a prototype and workflow in Google Tilt Brush.
Below we go into greater detail for each prototype.

Play-Doh Prototype

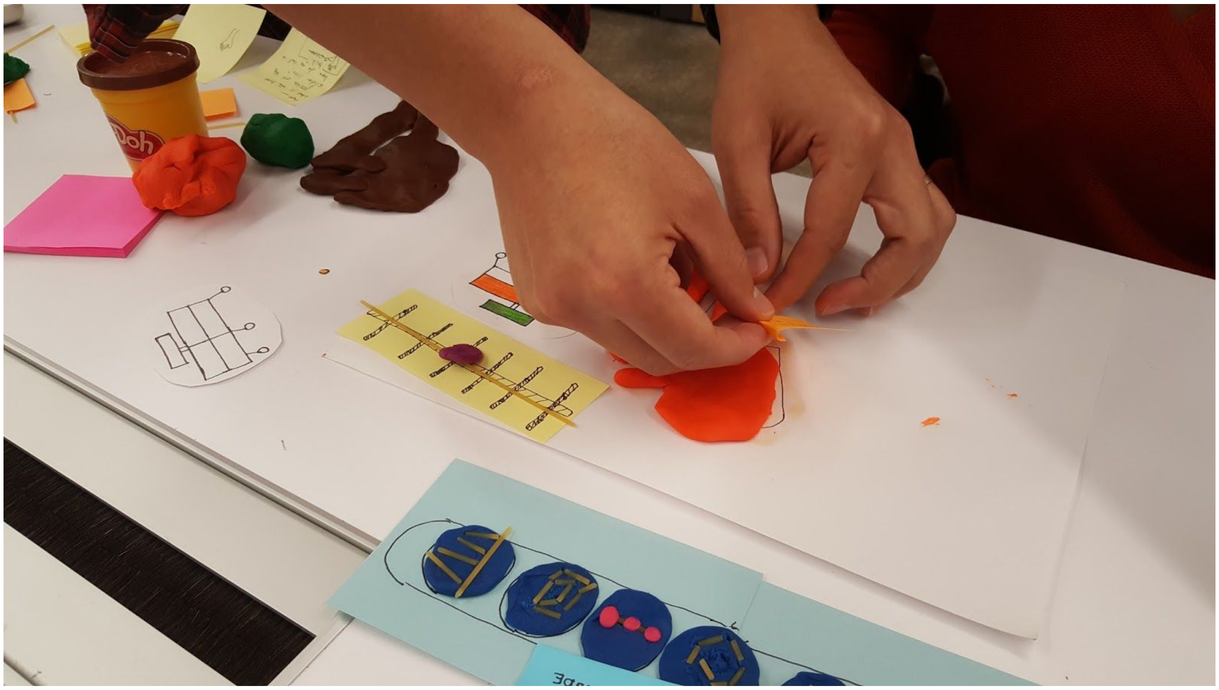
During week 2, we sat down in the NYU Tandon Makerspace and prototyped using play-doh, pasta, paper, and pens. This prototype enabled us to discuss early ideas for the hierarchy slider, GUI bar, and selection coloring, as well as general notions and sentiments about the problem.



Prototyping Session



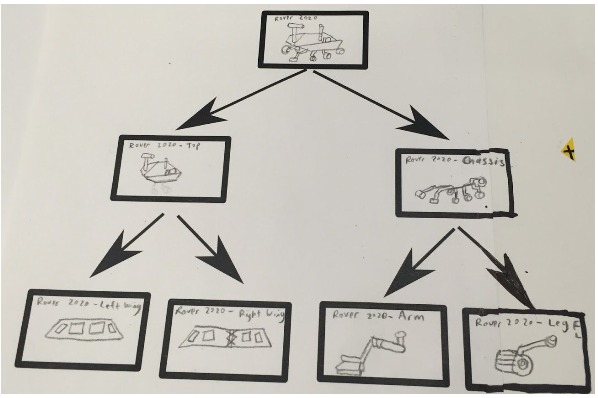
Pasta, Paper, Play-Doh GUI bar.



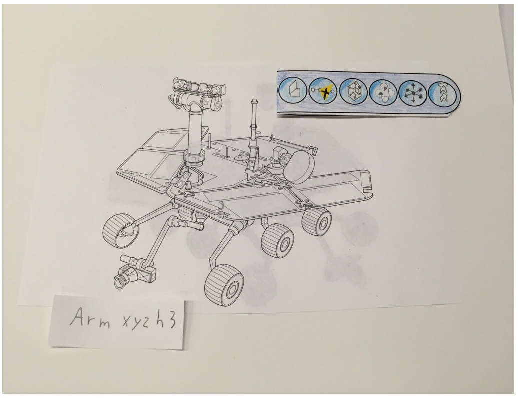
Color coded arm on paper (orange selected, brown unselected), Hierarchy slider (yellow), and new GUI (blue).

Paper Prototype

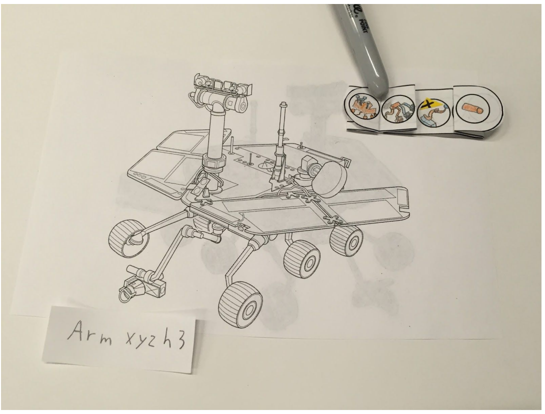
During week 3, we constructed a paper prototype from printed line drawings and hand drawn and cut illustrations, highlights, and colorings. We designed a perfunctory version of the NavTree, the iconography of the GUI bar, and a hiercharchy bar, which used illustrated buttons to describe states in a path on the hierarchy tree. Please note that we later opted for a continuum slider instead of a bar. We also designed the concept of pinning.



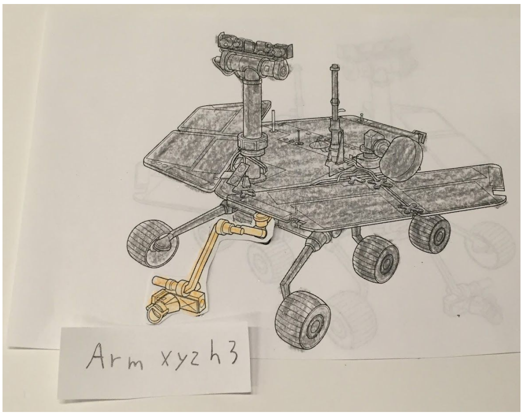
NavTree Prototype, drawings on printed tree.



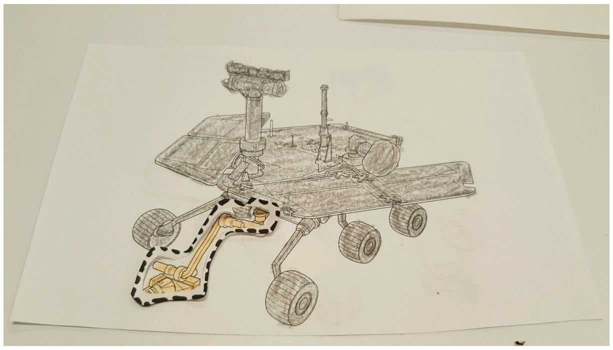
Rover image with part label and GUI bar.



Part label and illustration based hierarchy bar.



Selection in yellow, non selection grayed out.



'Pinned' robot arm denoted by broken line.

Cardboard Prototype

During week 4, we constructed a cardboard prototype that features a full-sized rover, a mini-rover, and a 2D printed NavTree. We then used the prototype in user testing sessions.

User testing session setup, explodable mini rover (left), full rover (middle), and NavTree (back right).

View with hierarchy slider (held center). Note: slider is used as a conceptual continuum, rather than a discrete set of illustrated buttons.

Head Mounted Display (left user), NavTree (held center), rover (left table), and mini rover (right table)

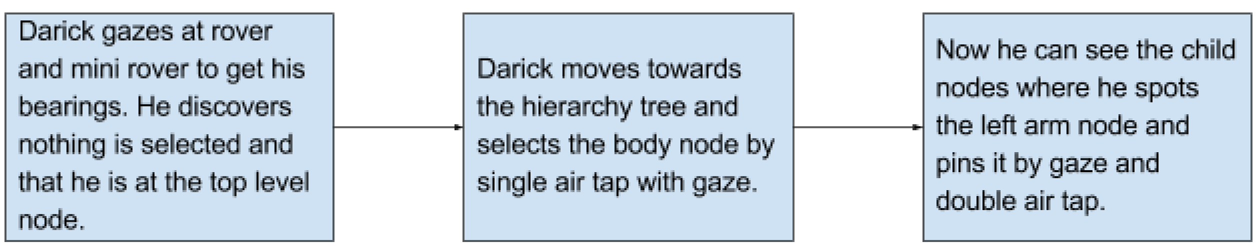
10 & 11. Storyboards of User Flows and User Journeys

Darick

Darick is a member of the newly founded inflatable robotic team at NASA, where they are working to use the technology from Carnegie Mellon University that inspired the fictional robot Baymax in future mars rovers. They are currently considering an anthropomorphic design with a hierarchical structure similar to a human skeletal structure. His team is currently discussing matters of symmetry and weight distribution, since they want to use each skeletal arm for a different task in future mars missions. They are using a hololens to facilitate their communication efforts. Naturally Darick uses the NavTree interface, since he is very in tune with the abstract organization of the hierarchy.

Through the Hierarchy Tree Panel

Task: Select the left arm of the rover through the NavTree



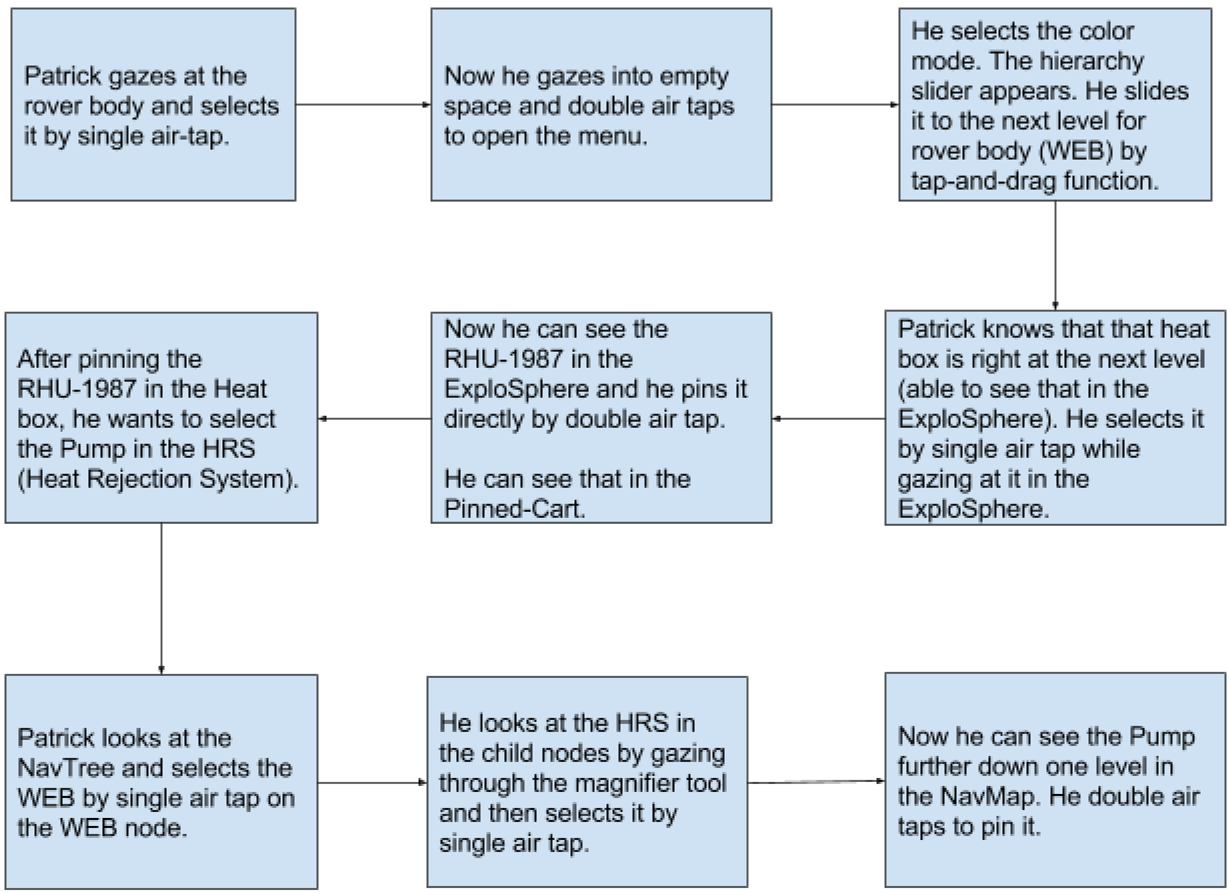
Patrick

Patrick recently worked on developing the heaters to keep the rover warm on Mars, especially during night time when the temperatures can drop below -140 F. He would like to inspect a particular RHU(Radioisotope Heater Unit) inside the WEB(Warm Electronic Box) or commonly known as the “Rover body” as well as

Pump inside the Heat Rejection System(HRS) to check for the heat dissipation system.

Through the Big Rover(Sphere) and NavTree

Task: Pin RHU-1987 inside the rover body through the ExploSphere and pump in the Heat Rejection system

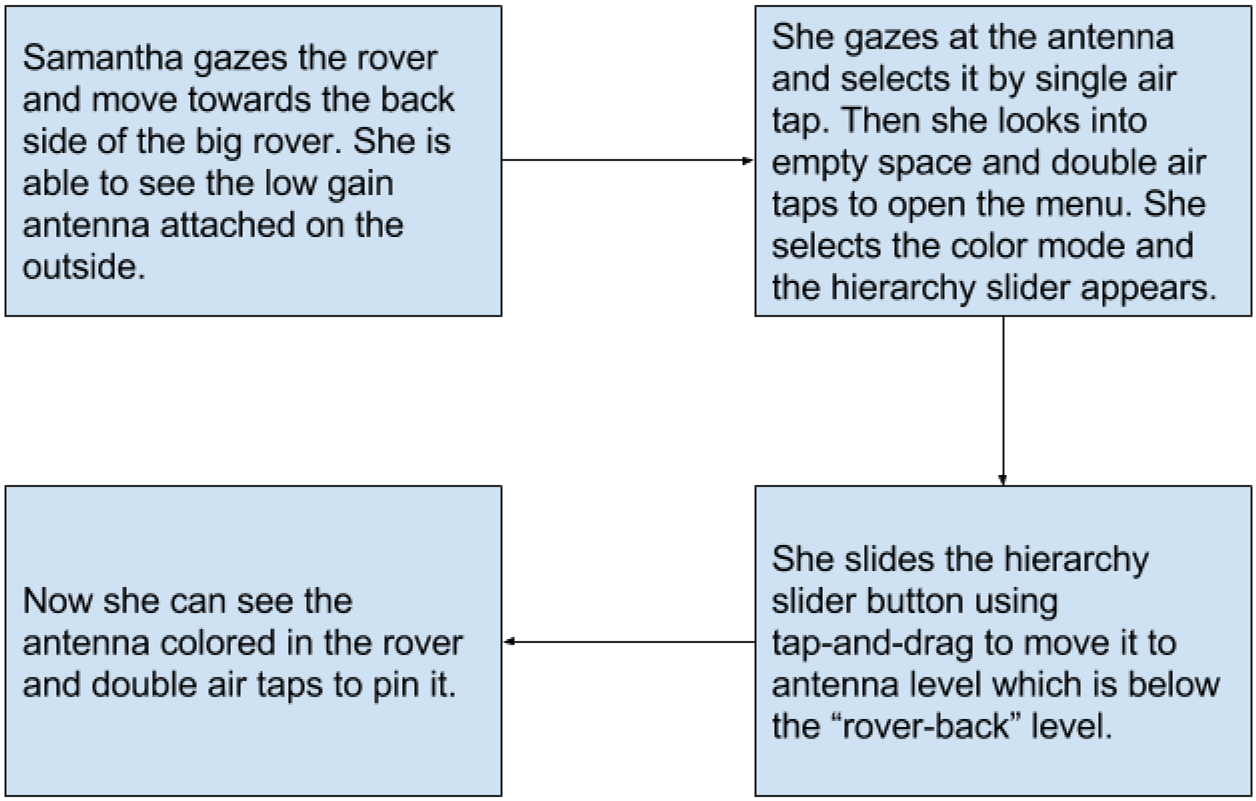


Samantha

Samantha is working with her mentor on the communication team for Mars 2020 Rover. She has got the task to analyse the low gain antenna that is located on the rover equipment deck or the “rover back”.

Through the Big Rover

Task: Pin antenna present at the back of the rover.



11. User Testing

Introduction

Our target user group was mechanical engineers with experience working on the Mars 2020 Rover. A sample of 5 engineering students participated in our usability testing of the cardboard physical prototype. Participants were comprised of three Mechanical Engineers, a Computer Scientist, and a 3D Animation and Virtual Reality production student. Two out of the three Mechanical Engineers were part of a Mars 2020 Rover project at NYU, designing a new chassis for the rover.
User testing took place at the NYU Maker Space, and students in and around the Maker Space were invited to participate in the testing. Participants were read a script that explained they would be testing new features in NASA's Protospace application and they were encouraged to think "out-loud," so we could record their feedback. Users also signed a form to consent to the audio-recording of the testing session. The script included a description of the following gestures:

- Select: Gaze at an object, and single air-tap
- Open Menu: Gaze into empty space, and double air-tap
- Pin an Object: Gaze at an object and double air-tap
- Undo: Gaze into empty space, and single air-tap air-drag.
- Use a Slider: Gaze at slider and single-tap air-drag

Participants were presented with a cardboard head mounted display (HMD) to wear to simulate the field of view (FOV) of the Microsoft Hololens, and cardboard models on a table and held aloft by team-members were presented to participants as the virtual augments in their FOV. The primary tasks given for testing were to: Select and pin the whole robotic arm, and select and pin a screw inside the robotic head.

User Testing Research

Based on the task given, to "Select and pin the whole robotic arm, and select and pin a screw inside the robotic head", what follows is the feedback from each participant tested.

User 1: Female, 3D Animation and VR production student

VR/AR Experience: Experience using multiple applications and technologies in VR & AR

This first student identified gaps in the workflow of our model. Before further testing, we iterated on our prototype to incorporate the lessons learned from this session.

- The user pointed out that it wasn't clear what part they were selecting at any given time. The user suggested that, by default a user selects the lowest object on the hierarchy.
- The user was unclear what the NavTree would display. She suggested that the NavTree would display only 3 levels of the hierarchy, with the selected items in the middle level.
- Regarding the mini-rover, the user suggested that only the last item selected be shown in the exploded view. Also, that all the "pinned" objects appear as "icons" surrounding the exploded view.
- In order for the user to know how many items are pinned, she suggested an "amazon shopping cart" style button, with the number of objects be added to the Floating menu. When a user selects this feature, a dropdown of all selected items appear.

User 2: Male, Computer Science Major

VR/AR Experience: Experience using Google Cardboard

- The user did not use the Mars Rover to complete both tasks, only the map.
- The user completed the tasks very quickly and said the map was extremely helpful.
- The user liked the idea of the exploded view, but did not need it to complete the tasks.

User 3: Female, Mechanical Engineer

VR/AR Experience: None

- The user had difficulty comprehending that the default selection was the lowest level of the hierarchy. User assumed she could keep selecting and pinning items until the whole arm was selected.
- The user ultimately selected both items using the Menu, and did not engage with the NavTree at all. The user did not find it useful.

User 4: Male, Mechanical Engineer, Experienced using CAD software for a Mars Rover project

VR/AR Experience: Pokemon Go, Google Cardboard, HTC Vive

- The user found the NavTree easiest to use.
- The user liked the feedback given across the 3 objects, but felt it was too much information to have the three objects “on” at the same time. The user suggested being able to toggle the new UIs on and off.
- User was concerned with 8 sub-assemblies being too big for the NavTree -- felt that our representation of three levels was too simplified.
- The user suggested using a Roulette wheel to move between child objects if there were many
- The user suggested that when using the Hierarchy slider, that the slider be able to turn 90 degrees, and then all the objects at that level would fly out to the sides.
- The user suggested that a person be able to pin object directly from the hierarchy slider, not after.
- Since this user worked with the Mars 2020 Rover, they told us that in their experience, each parent object had about 16 child objects.

User 5: Male, Mechanical Engineer, Experienced using CAD software for a Mars Rover project

VR/AR Experience: Experience using Google Cardboard

- The user felt that our workflow was easy to use, and straightforward
- The user liked the NavTree the best as a way to navigate through the parts.
- The user felt that it was not clear that the default selection was the item that was lowest on the hierarchy
- The user felt that the NavTree should be 2D, not 3D, (as we had represented it) since he felt items may get lost in 3D
- The user suggested that the NavTree should show 2 Upper levels of the hierarchy not just one, because knowing two higher helps orient a user.

12. User Testing Analysis & Findings

Based on user testing, we found a number of insights, prompting us to iterate on our prototype.

1. Most users found the NavTree extremely useful, and once they discovered it, they used it as their sole navigation.
   a. Even though it was pointed out that our representation of the NavTree was too simplified, in our next iteration we decided to keep it. We realized we needed to re-design it if showing three levels of the map would yield over 200 parts at the lowest level (if, on average, each parent has about 16 child sub-assemblies)
2. Users had trouble knowing they were on the lowest level of the hierarchy.
   a. We realized this was really a fault of explanation, and the limitation of our prototype. In digital space, it would be obvious to a user what they are selecting.
3. Despite existing in 3D space, the users wanted the NavTree to be in 2D.
   a. We asked each user if they prefered a NavTree in 2D or in 3D, and each one expressed a desire for it to be in 2D, stating that objects could “get lost” in 3D. In order to get more benefit from the map existing in 3D space, we decided to add a feature where a user could drag around the map where ever they wanted in the 3D space.
4. The more feedback, the better
   a. Even though an object was pinned, and in our case, would be surrounded by a dotted lines, some users wanted more -- for example, one users suggested having a button like a shopping cart, that told you how many items are pinned.

13. Project presentation deck

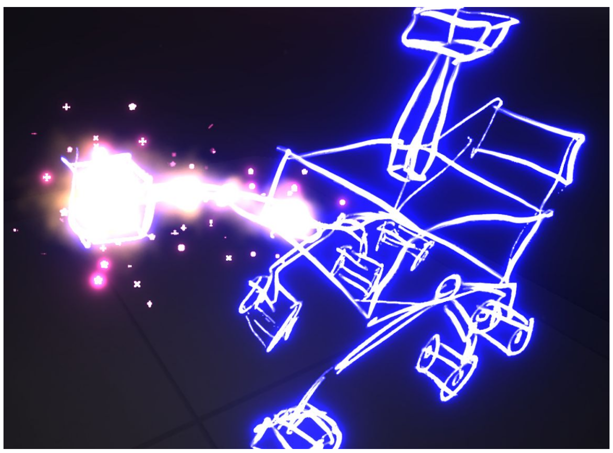
Here is a link to the presentation that we gave to the JPL representatives on November 7th, 2016.

https://docs.google.com/presentation/d/1SV1TbbfpUyIy72yEc_8g_xGDTp438Lta7kUi9jL0izs/edit?usp=sharing

14. Final Prototype

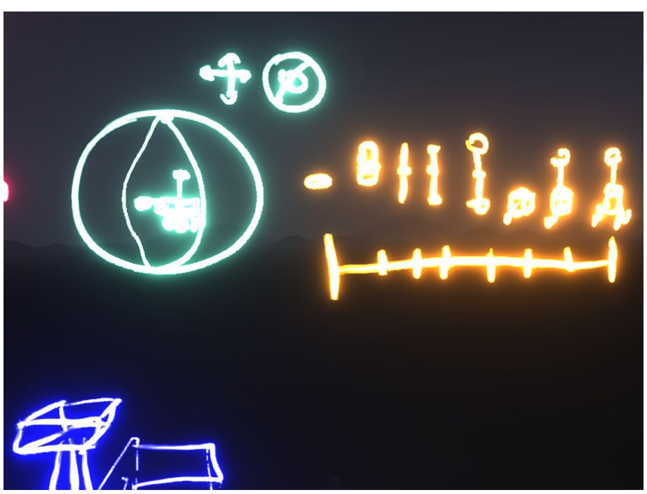
Google Tilt Brush

During week 5, we went to the Black Box theatre and constructed a final prototype based on Google Tiltbrush. We incorporated feedback from the critiques of our demo and a brainstorming session where we had an in-depth discussion of the roles of the mini-rover and the NavTree. We decided to go with a redesigned NavTree featuring breadcrumbs, single level parent - children views, gaze region stable enlargements, moving the NavTree in space, hiding it from view binarily, and the gazed part label. We also decided to place the mini-rover within a visually distinct sphere to clarify its distinction from the actual rover. We now call it the ExploSphere.

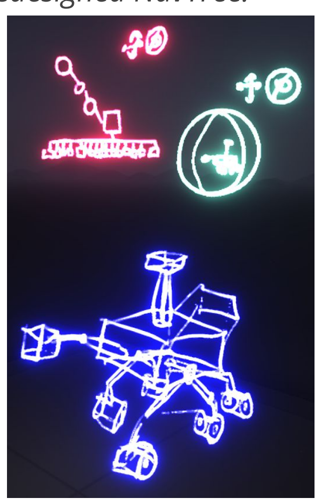


Selected Arm.

Redesigned NavTree.



Hierarchy Slider (yellow) with parts illustrations.



NavTree, ExploSphere in context.

15. Final Prototype

Here is a link to the presentation that we gave to the UX class on November 14th. We gave the presentation 1 week early, because some of our team members anticipated having important life events during the week of the 21st.
https://docs.google.com/presentation/d/1x9vjLnwjLDoEUvixWqN0_UT6zyWrsEM_4PP7M8rGEY4/edit?usp=sharing

We received feedback, where we learned that people found our use of Titlbrush screenshots to be unclear. We then decided to move over to using illustrative animated gifs in our final communication tool.

16. Project Communication Tool

Our final Communication tool is a website hosted at the following address:
https://bryce-summers.github.io/UX_Team_AdaLovlace_Communication_Tool_IDM_F16/