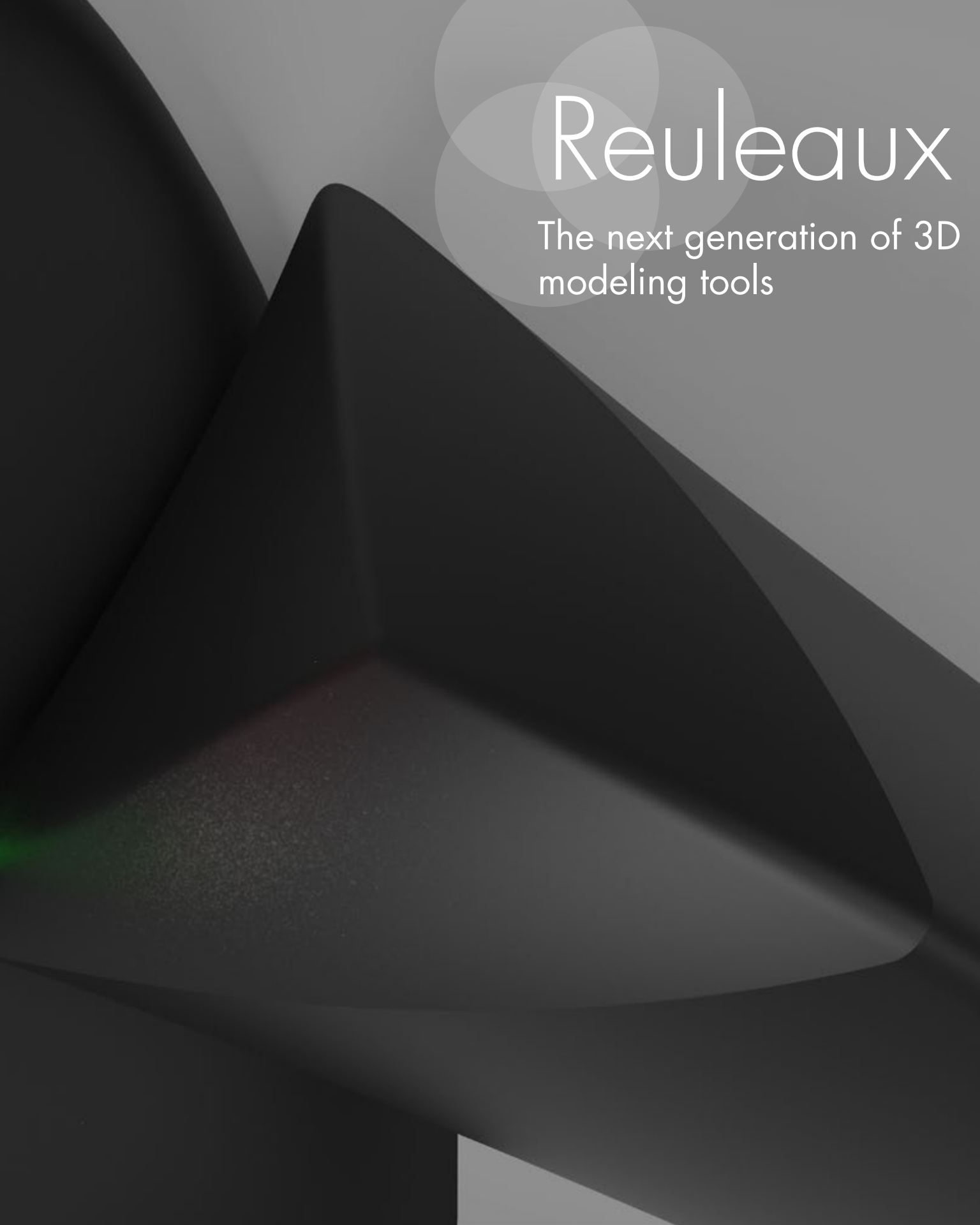
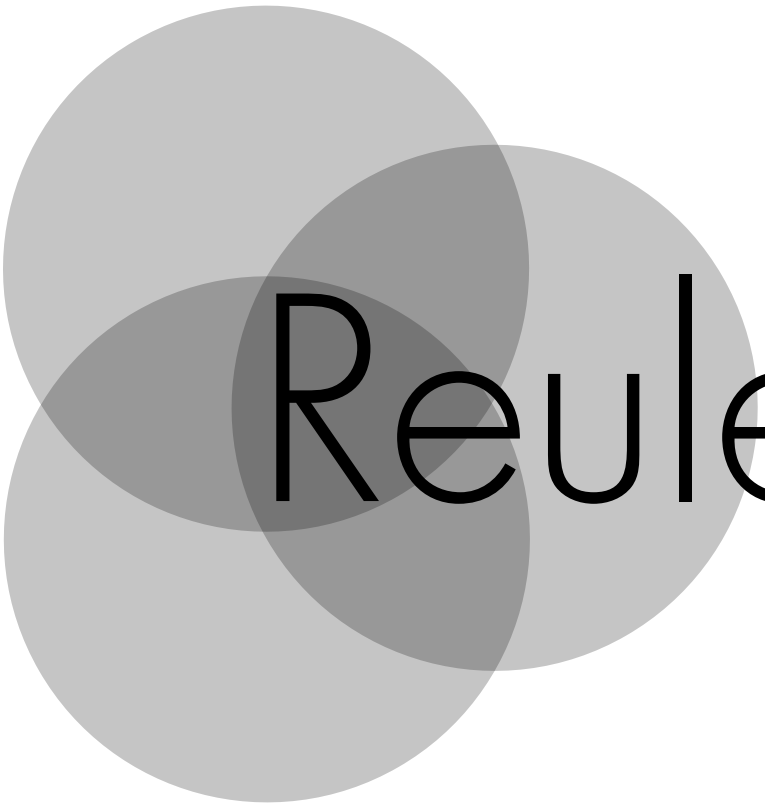
5-1-2018

Reuleaux

Sidney Miller
Thomas Jefferson University


Reuleaux
The next generation of 3D modeling tools

Sid Miller

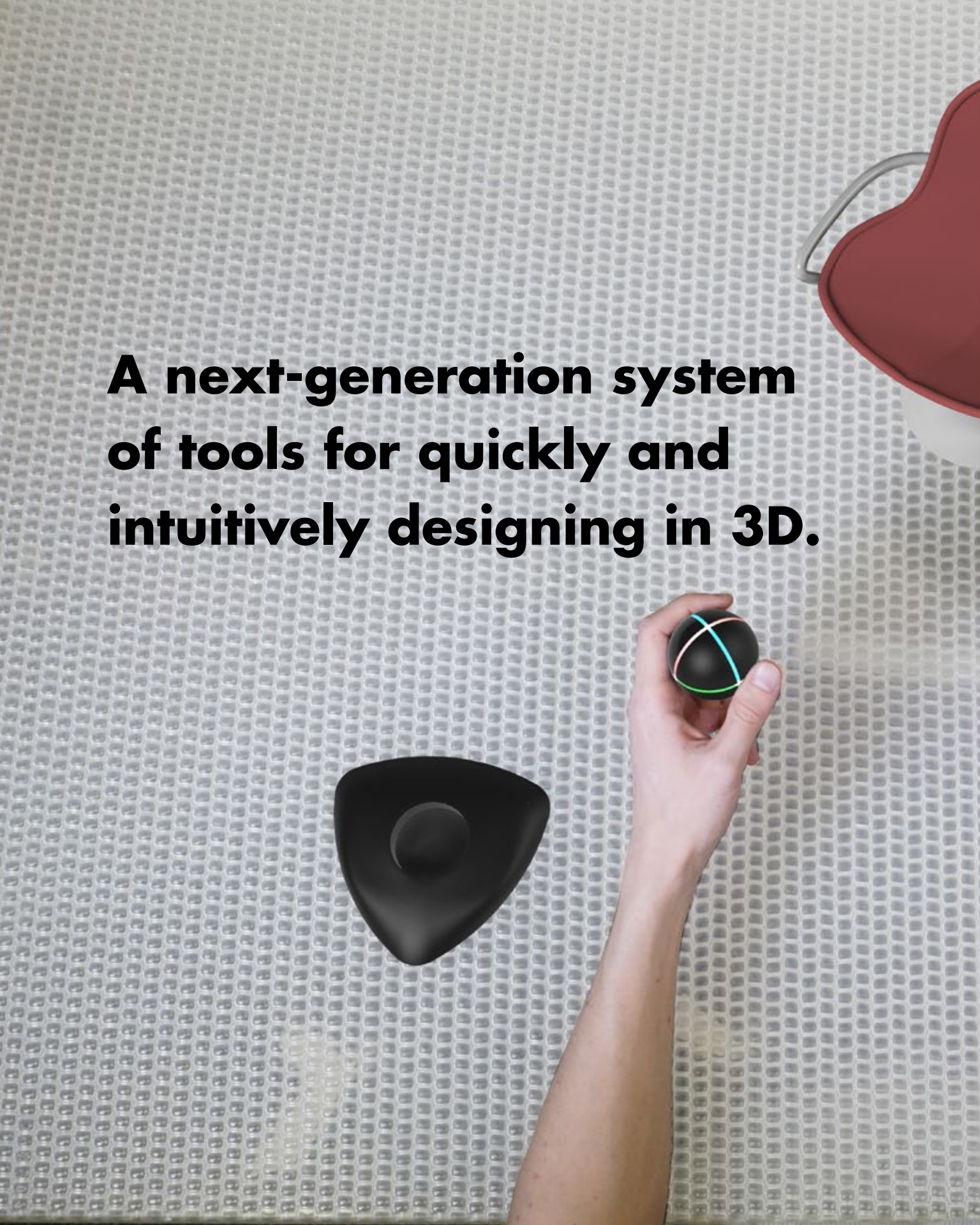

Reuleaux

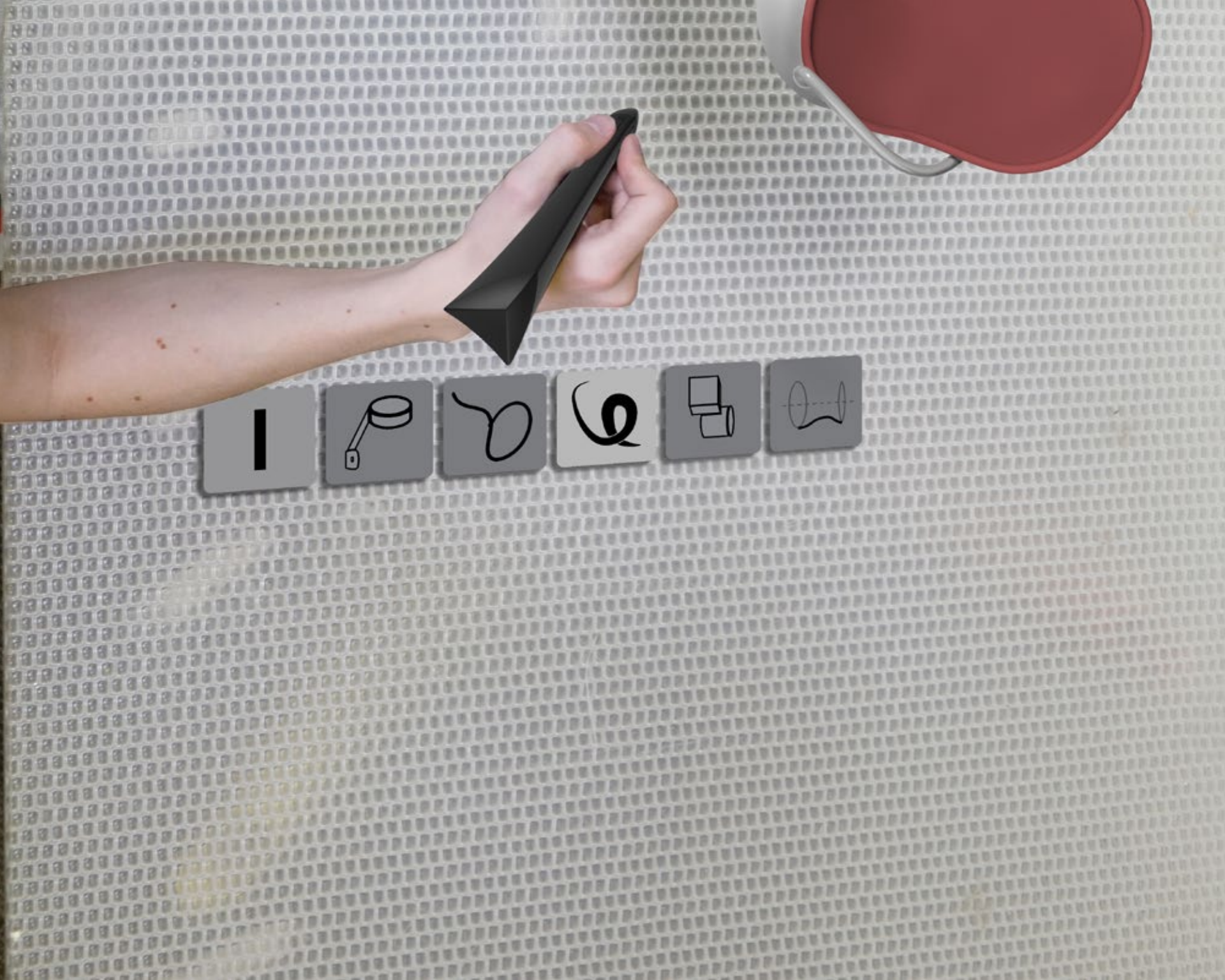
1

Background

How do you design for the future, based on what is known right now?

The future is promised to us in a million ways by movies, TV, and books. But we still don't drive flying cars or have robot servants. This amazing science fiction vision of the future is just that, a fiction. With my capstone, I challenged myself to create a tool for designers of the future, rooted in the practical, everyday realities of the job. I wanted to push myself outside of my comfort zone and understand what it takes to design a product on the cutting edge of technology.


A next-generation system
of tools for quickly and
intuitively designing in 3D.



2

Research

Experts Consulted

Design Consultant

Eric Schneider
Phase One Design

3D Technology Engineer

Hans Kellner
Autodesk

VR Designer

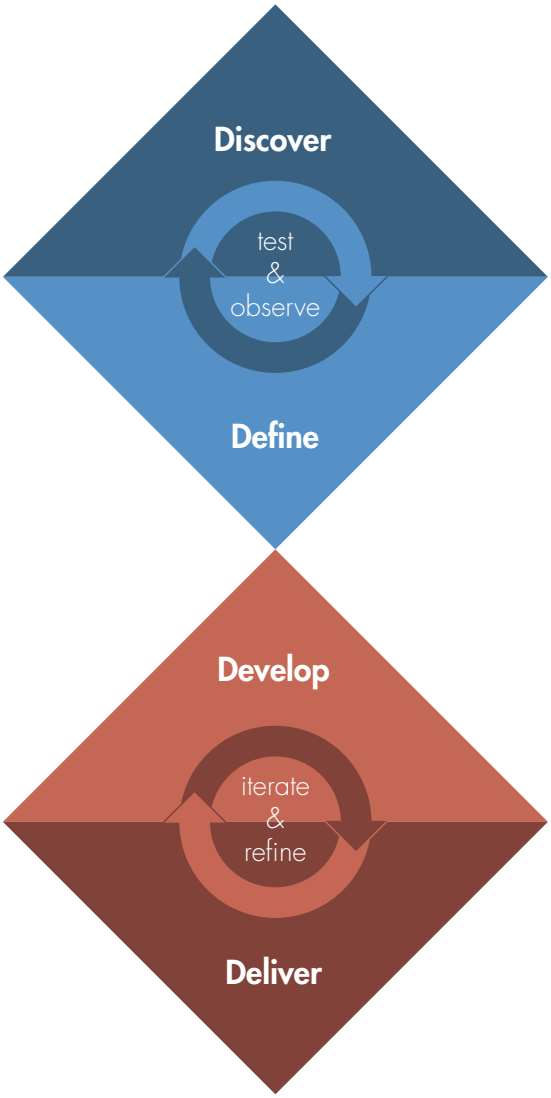
Claire Gottschalk
Valve

Eric Schneider has decades of experience as a design consultant. His insights into the day to day life of a designer have been instrumental in my project. He is also an expert on designing for manufacturing and helped me to validate my proposed design, both physically and functionally.

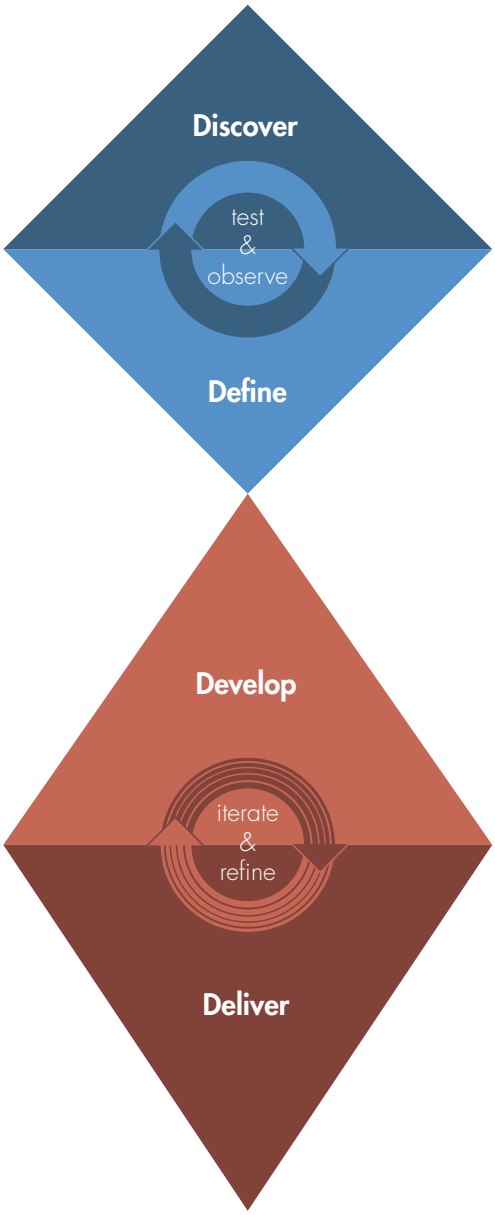
Hans Kellner is an engineer at Autodesk, one of the largest software companies in the 3D modeling market. His job includes exploring new technologies, such as virtual and augmented reality, and how the Autodesk can leverage them in their products. His experience with the 3D modeling landscape and how it is being effected by new technologies gave me insight into the interactions that users have with their tools. He helped me to validate my concept as a 3D design tool.

Claire Gottschalk is the Principal Industrial and User Experience Designer at Valve Corp. She was instrumental in the design of the HTC Vive VR system, the industry standard system on the front line of an exploding market. As an industrial designer knee deep in cutting edge technology, Claire has insight into my target users, and into the current state of augmented and virtual reality.

The Design Process



The double diamond is an easy way to explain the design process. Starting with a problem, doing research, defining the actionable items, narrowing to specific goals, developing concepts, iterating and prototyping, and then delivering them as a finished design. When talking with people about their design process and how projects go, the reality of it is much messier and less linear.



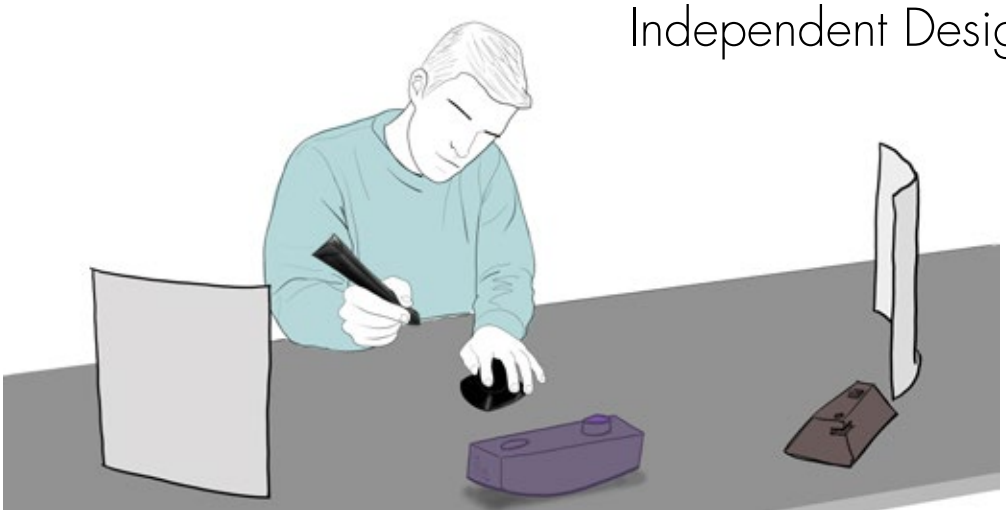
Many designers told me that often times the most frustrating, drawn out part of the process is near the end. Designs are prototyped or sent out for samples, but they come back weeks later, not quite what the designers expected. Showing clients an early prototype sometimes causes them to change their minds and sends the whole process back to the drawing board. There is clearly a breakdown in communication here.

Industrial designers are working on 3D products, but are held back by tools that limit them to working on 2D screens and pages.

Designers are used to talking about form, scale, and proportions and being able to visualize these things based on sketches and drawings. However, when presenting ideas to clients or colleagues, it is easy for them to misinterpret the information, leading to skewed expectations or doubt in the ideas merit.

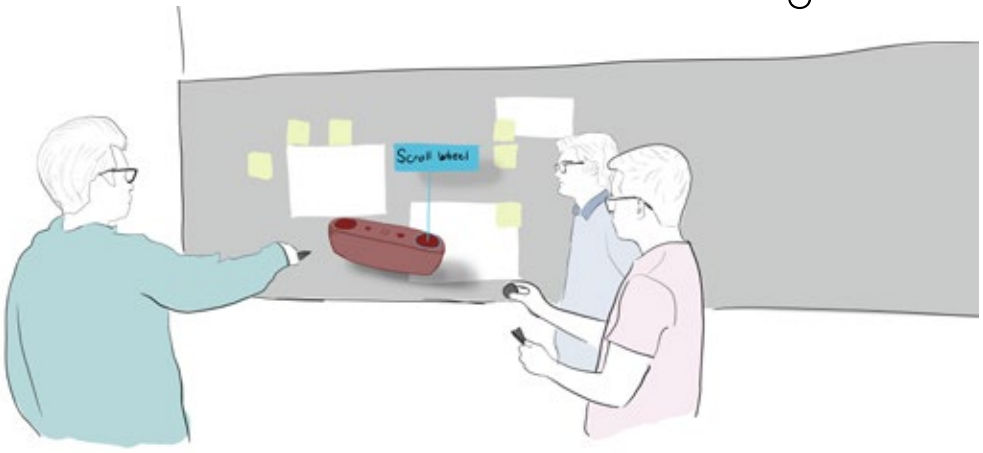
Designers transition between all different work situations. A practical tool must be versatile enough to cover those bases.

Independent Design



Collaborative Design

Design Review



Tool Study

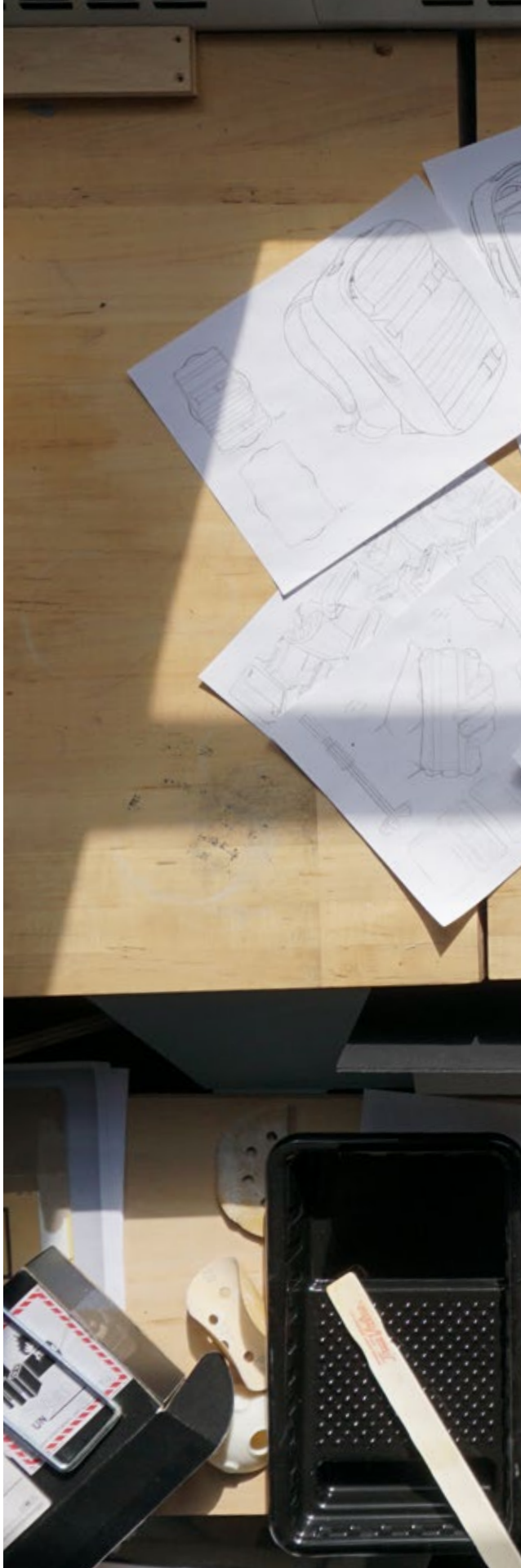
I explored the tools that designers are currently using. I asked designers why they choose one tool over another for certain tasks, what the most helpful features are, and what the most frustrating aspects of each tool are.

Tool Study

Hand Sketching

+ Direct tactile feedback
+ Quick and iterative
+ Portable
+ Easy to do while talking to collaborate

– Limited by materials on hand
– Perspective and scale cannot be changed
– Limited to 2D
– Mistakes cannot be easily undone
– Making copies breaks up workflow



Tool Study

Model Making

+ Direct tactile feedback
+ 3D or 2D
+ Shows scale and proportion
+ Can demonstrate interaction and function

– Limited by available materials
– Slow and time consuming
– Expensive in materials and labor
– Mistakes cannot be easily undone

Humans (especially designers) are tactile and visual creatures. A direct, hands-on interaction will be more intuitive and allow for a smooth workflow.

Hand sketching and model making are both tactile, hands-on methods of working. That direct control is predictable and intuitive, allowing users to be creative and express themselves, without the tools getting in their way.

Tool Study

Photoshop & Illustrator

+ High fidelity results
+ Mistakes can be easily fixed or undone
+ Allows rapid iteration by duplicating and modifying versions

– No tactile feedback
– Perspective and scale cannot be changed
– Limited to 2D
– Unintuitive keyboard and mouse interface

Tool Study

Digital Sketching

+ Direct tactile feedback
+ Quick and iterative
+ Portable
+ Allows rapid iteration by duplicating and modifying versions

– Perspective and scale cannot be changed
– Limited to 2D
– Palm rejection and touch controls can be unreliable

Digital tools provide powerful features which allow for higher fidelity results and a smooth workflow, but they often sacrifice an intuitive interface to achieve it.

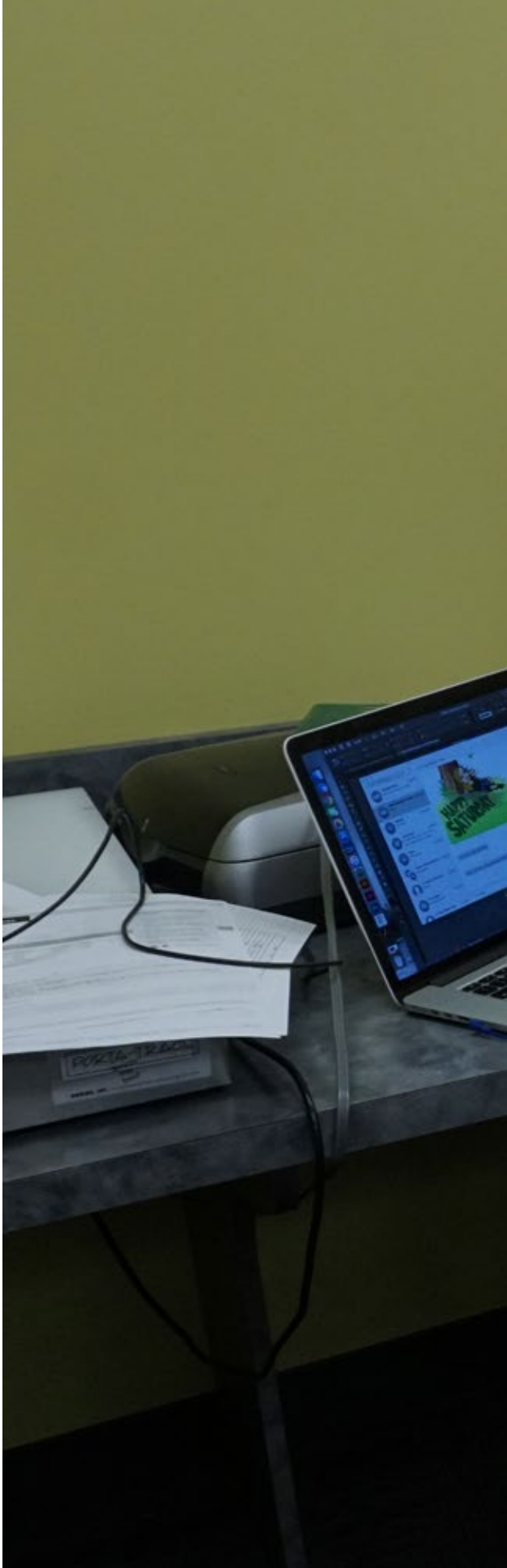
Features such as undoing mistakes, snapping to points and lines, and saving copies to make iterations have made digital tools surpass physical tools in many situations. However, many digital tools still lack the ability to share and collaborate in real time. Two people can draw on the same piece of paper, but only one mouse and keyboard work on a computer at one time. The next generation of digital tools must allow people to work together in real time, whether they are side by side or across the globe.

Tool Study

3D Modeling

+ Allows for accurate models which can be used for manufacturing
+ Can be used to create renderings and animations
+ 3D or 2D
+ Can show interaction and function

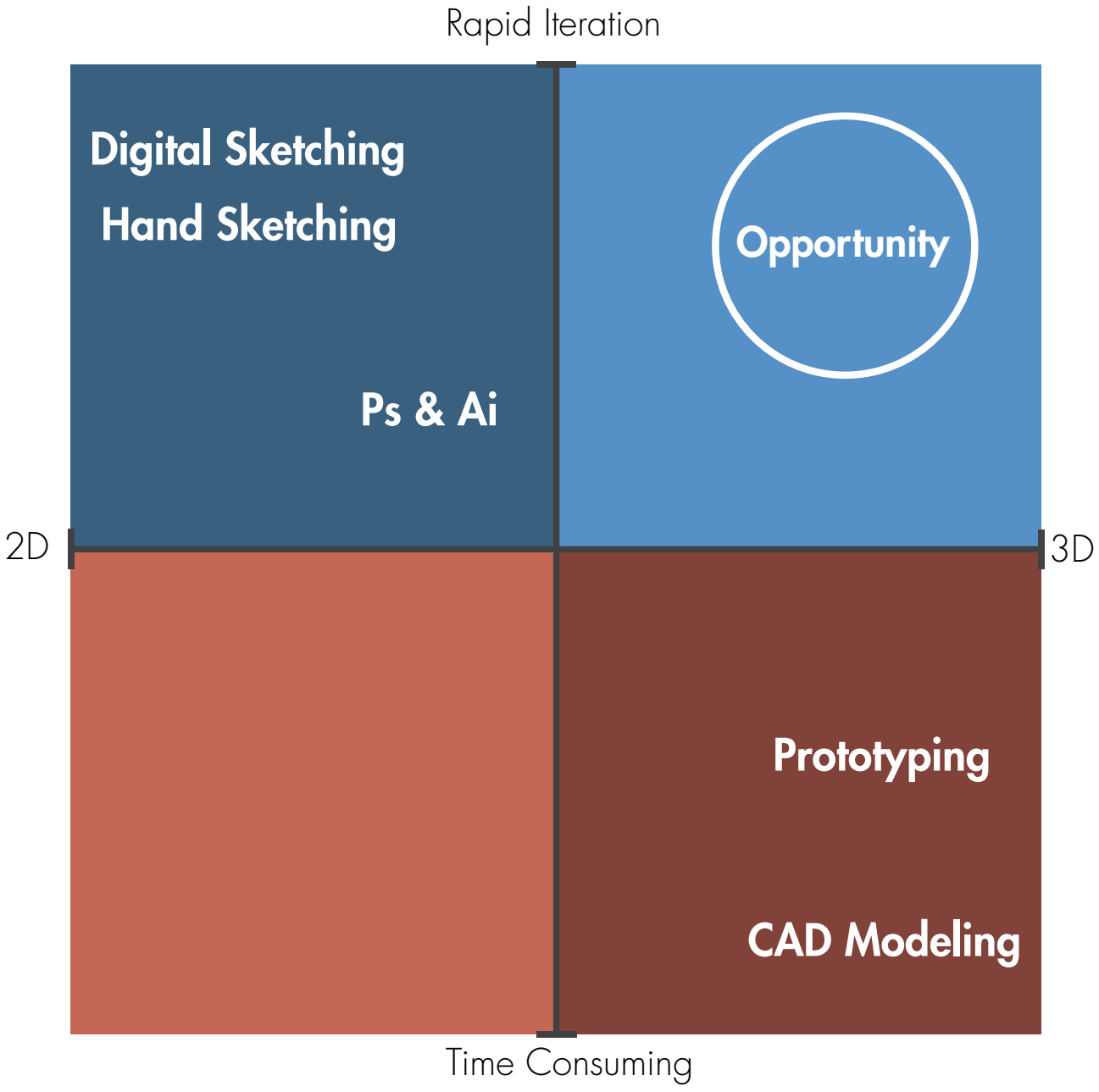
– Slow and time consuming
– Clunky, unintuitive mouse and keyboard interface
– One hand controls both view of model and tools to affect model
– 3D model on 2D screen warps perspective



CAD often distorts the proportions and scale of an object, resulting in a disappointing first prototype.

Many designers that I interviewed told me that the first physical model or prototype after 3D modeling a design is often different than they expected. The proportions or the scale look different in real life than they did represented on the computer screen. This phenomenon slows down the design process, requiring an extra round of sampling and the creation of more time consuming CAD models and prototypes. Displaying designs in 3D at 100% scale before a physical prototype is made would save time and money during the design process.

Opportunity

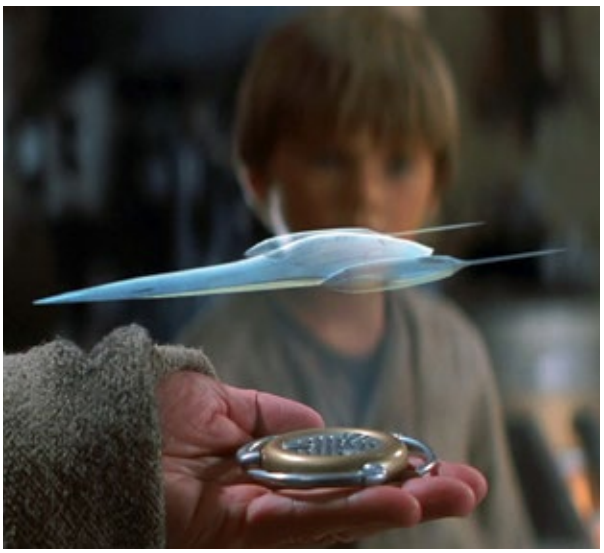


Studying these tools showed that there is a gap in the design tool kit. There is a need for a tool that allows for fluid design and rapid iteration, but functions in the 3D space. This would allow designers to work three dimensionally earlier in the design process, without sacrificing speed and flexibility.

Technology Study

I explored the rapidly advancing technology of virtual and augmented reality. These cutting edge systems allow users to see virtual information convincingly in 3D for the first time. I researched all of the current systems to see which ones are the most compelling, and which ones have the most refined experience.

What is mixed reality?



Mixed reality is a new way of interacting with computers which will change the way we work and play. Mixed reality is a spectrum, on which augmented and virtual reality are two points. VR immerses you in a completely new environment, while AR can bring information into the real world and allow you to interact with it in intuitive, physical ways.

These technologies come in many shapes and sizes. You can experience them from a headset, smartphone, or other device. As the technology becomes more advanced, these displays will be lighter, smaller, and less expensive. **However, without intuitive, precise tools that allow users to interact with information in 3D, mixed reality will never reach its full potential.**

Reality
real and unfiltered

Augmented Reality
the real world overlaid with digital content

Virtual Reality
an entirely new digital environment

Current Mixed Reality Controls

Oculus Touch Controllers

Thumb sticks and buttons modeled after video game controllers

LED tracking array wraps around hand to prevent user from blocking it

HTC Vive Controllers

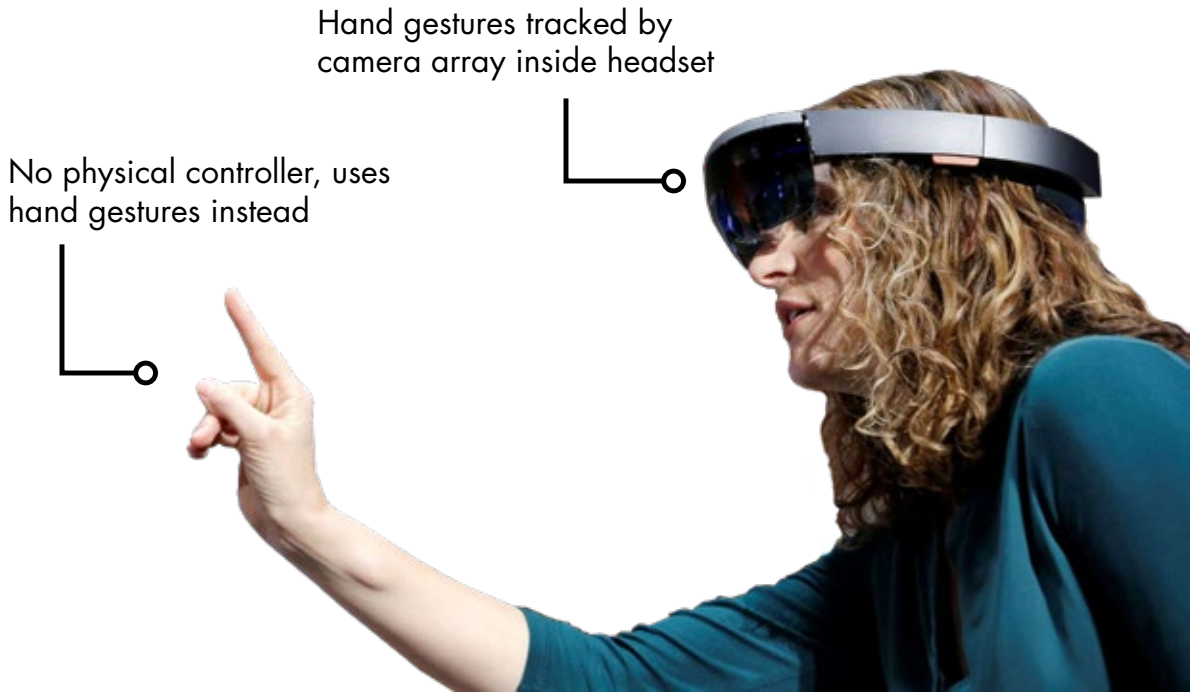
Sensor array is held out in front of the user's hands

Large touchpad provides main point of interaction

Held more like remote controls than game controllers

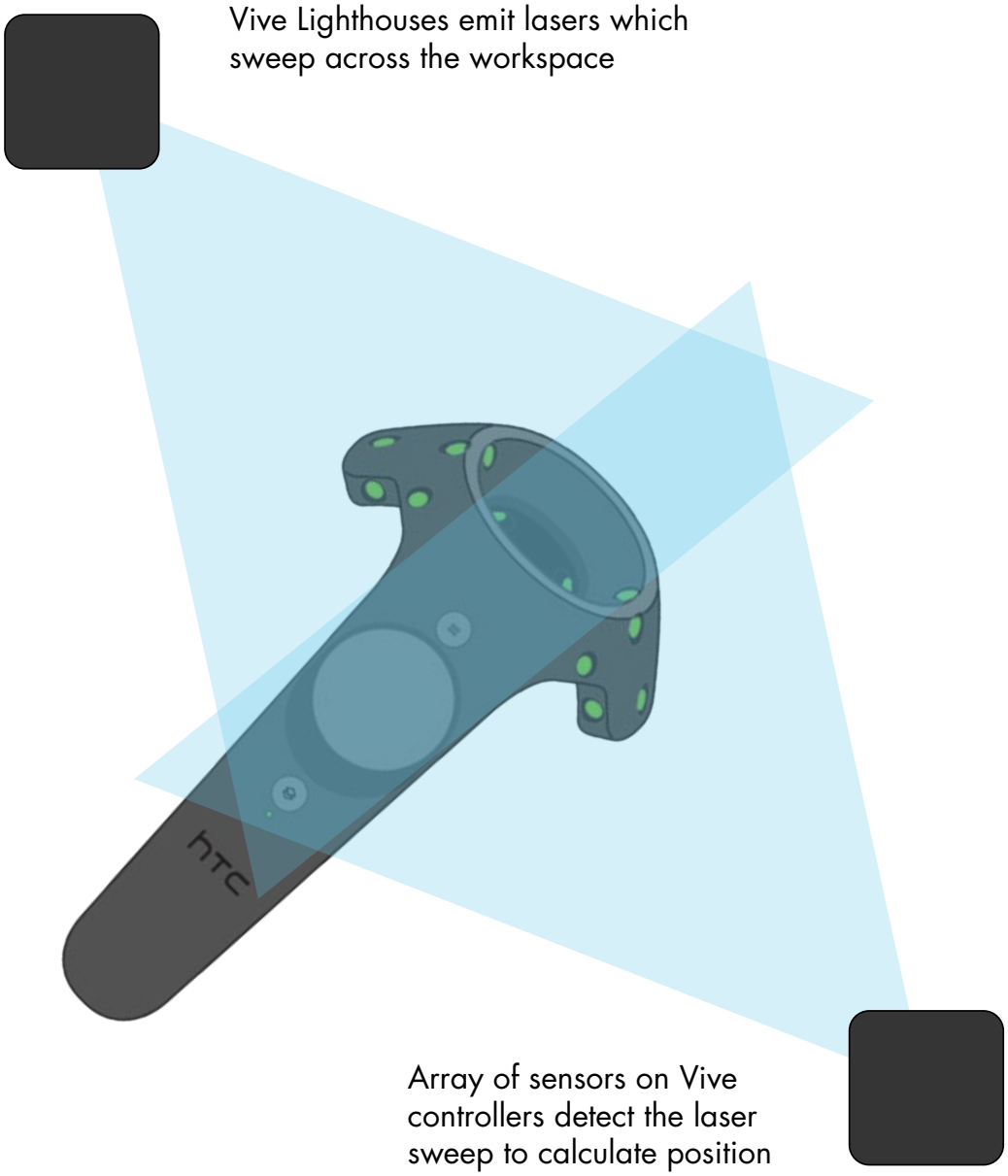
Microsoft Mixed Reality Controllers

HoloLens Gesture Controls

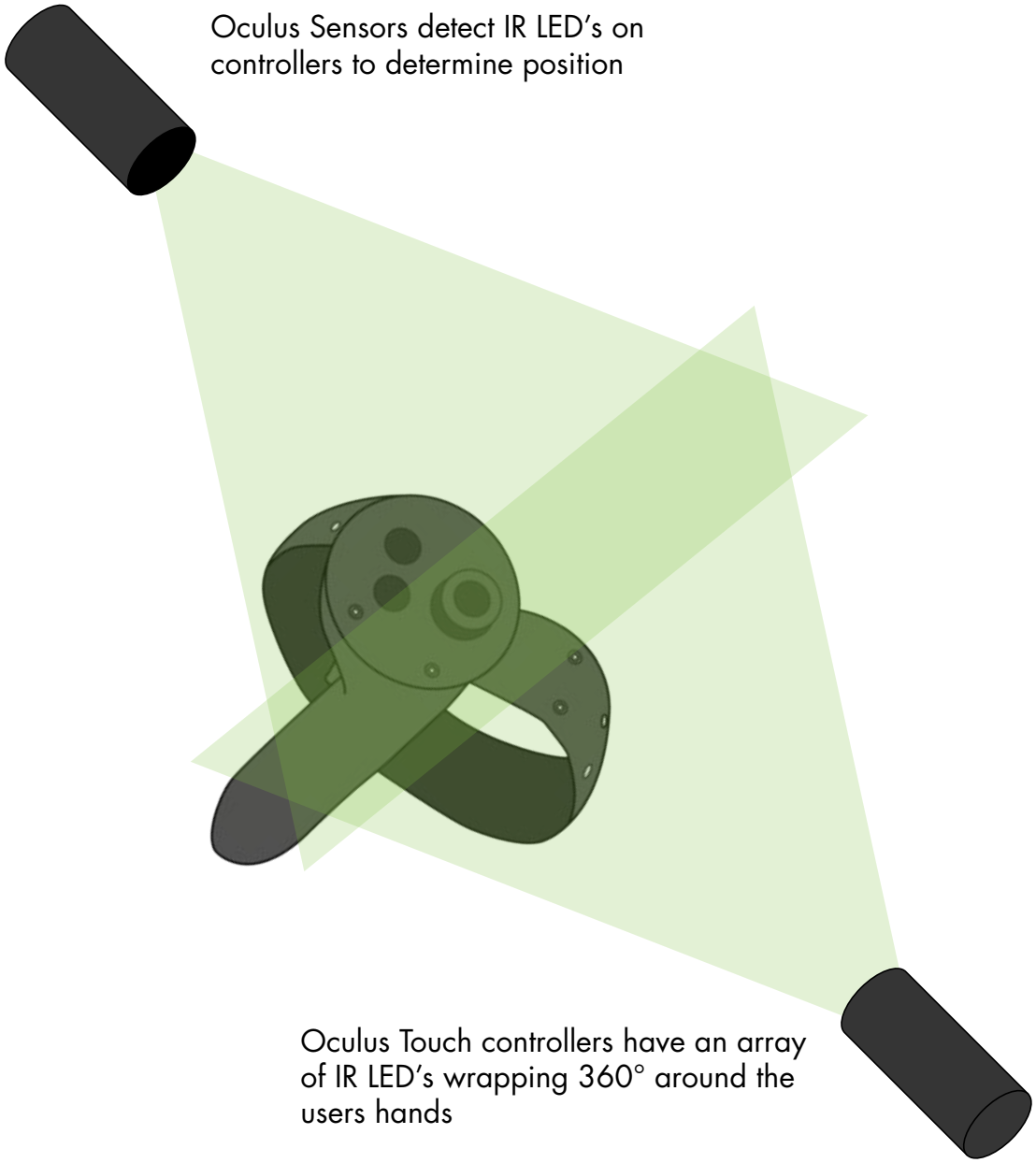


3D Tracking Technology

Inside-out Tracking: SteamVR

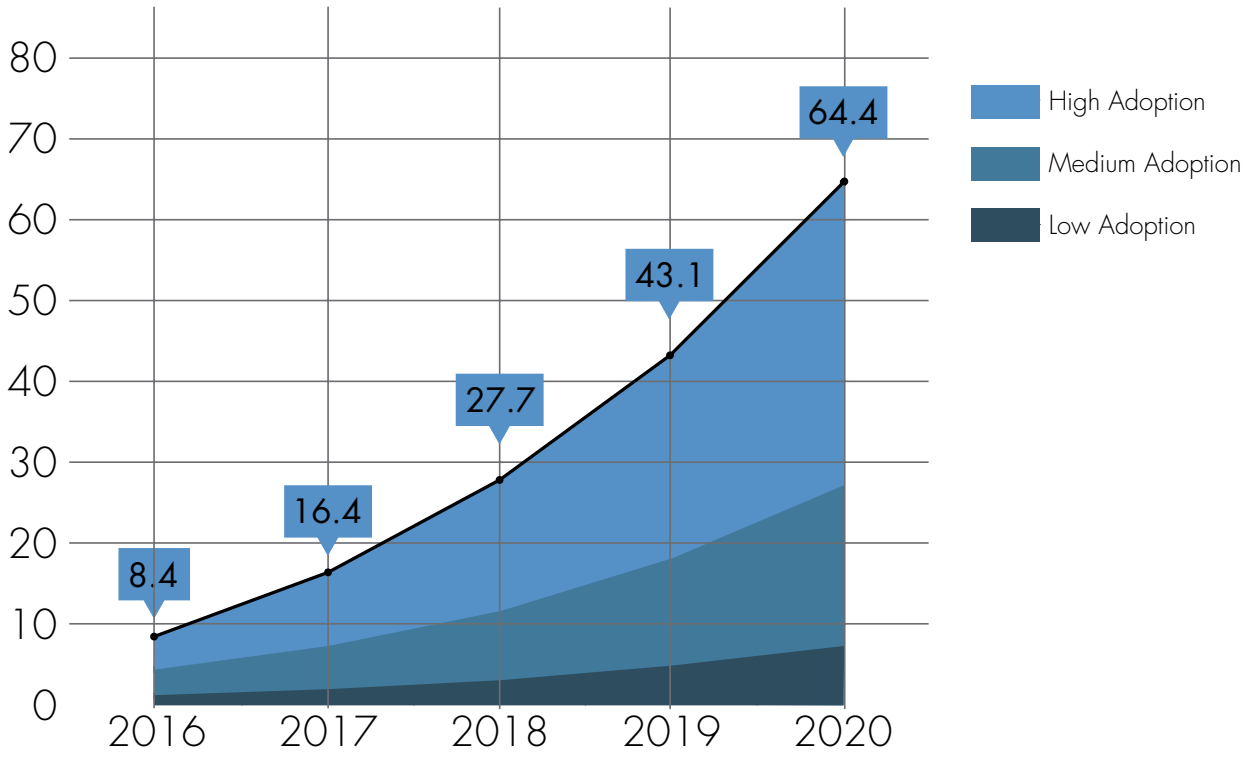


Outside-in Tracking: Oculus Constellation



Where is the market going?

Projected shipments of virtual and augmented reality device worldwide from 2016 to 2020 (in millions)



We are currently in the very 1st generation of virtual and augmented reality technology, with many of the current systems still in a developer phase, not available to consumers. But, the weight of the technology industry is backing VR and AR. Google, Microsoft, Apple, and Facebook are investing in this technology, counting on it being the next big advancement in consumer electronics. In addition, smaller companies are innovating in the market, such as Magic Leap and Meta.

These first generation headsets are heavy and clunky, and their displays are very limited, but they show a proof of concept and allow developers to begin creating tools and content.

As the display technology improves and new advancements are made, the systems will become lighter and more accessible. Just like the first generation of cell phones, in a few years, the first generation of AR will look like toys.

Conditions for Success

What features do designers need?

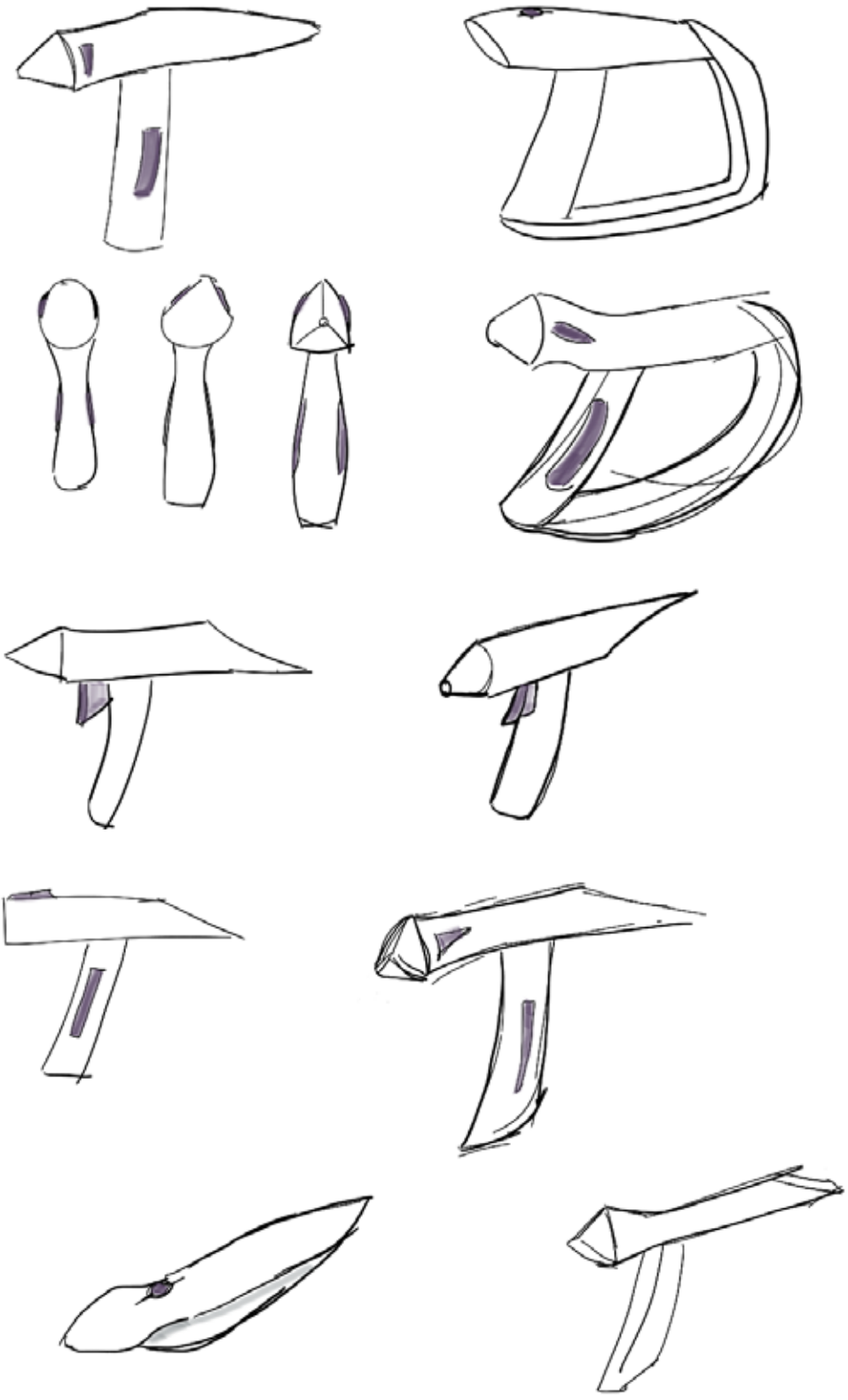
- Rapid creation of 3D sketches and models
- Accurate scale and proportion in 3D
- Demonstration of interaction and functionality
- Rapid iteration and collaboration by seamlessly duplicating and sharing models
- Independent, simultaneous control of model orientation and virtual tools
- Easily fix or undo mistakes
- Practical for individual, collaborative, and demonstrative scenarios

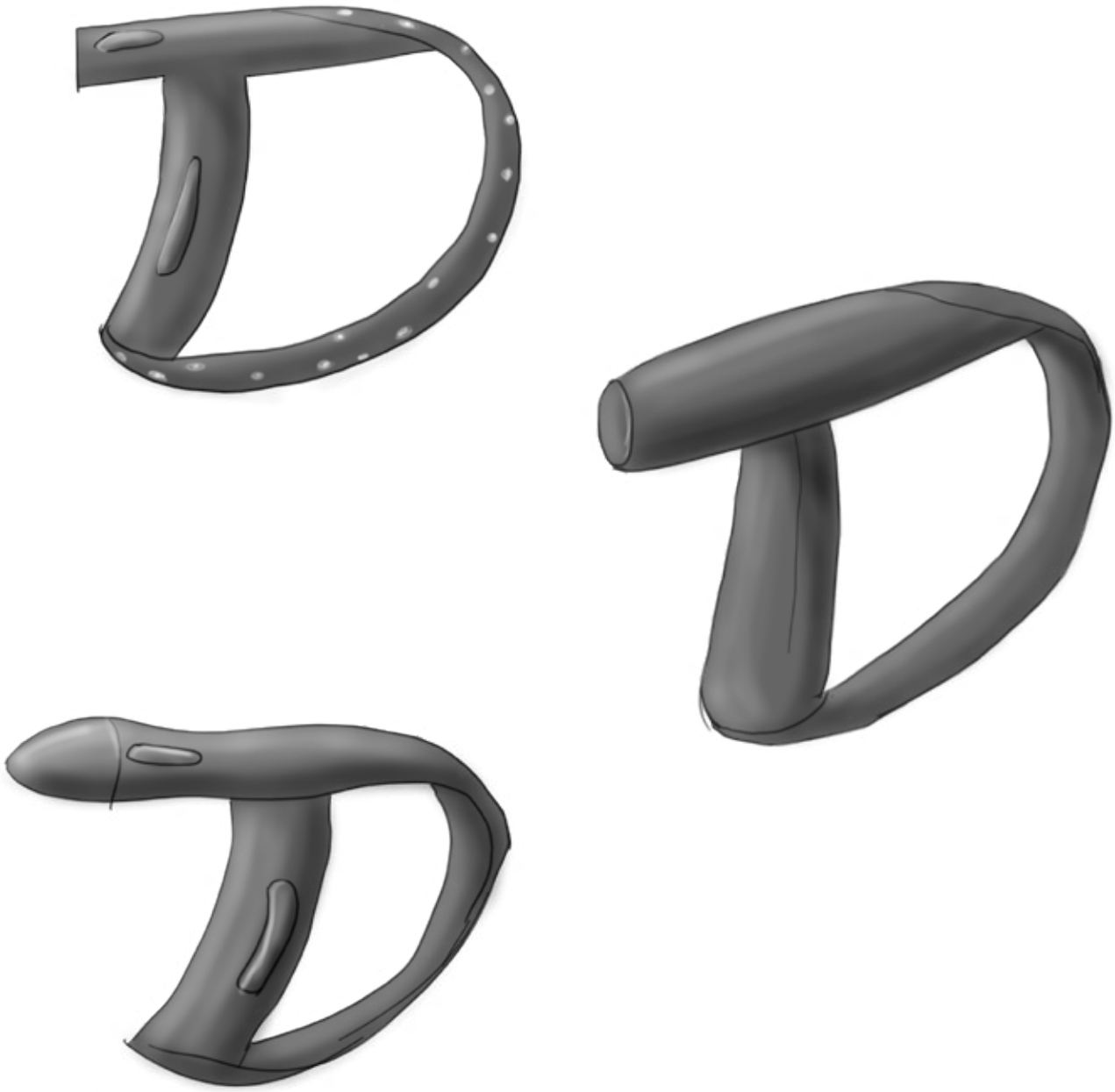

ATLAS
LONG
LIGHT
Pinch on Top/ Bottom
SHORT
LIGHT
BLACK PLASTIC
ATLAS
BATTERY
FOAM LIP
ATLAS

3

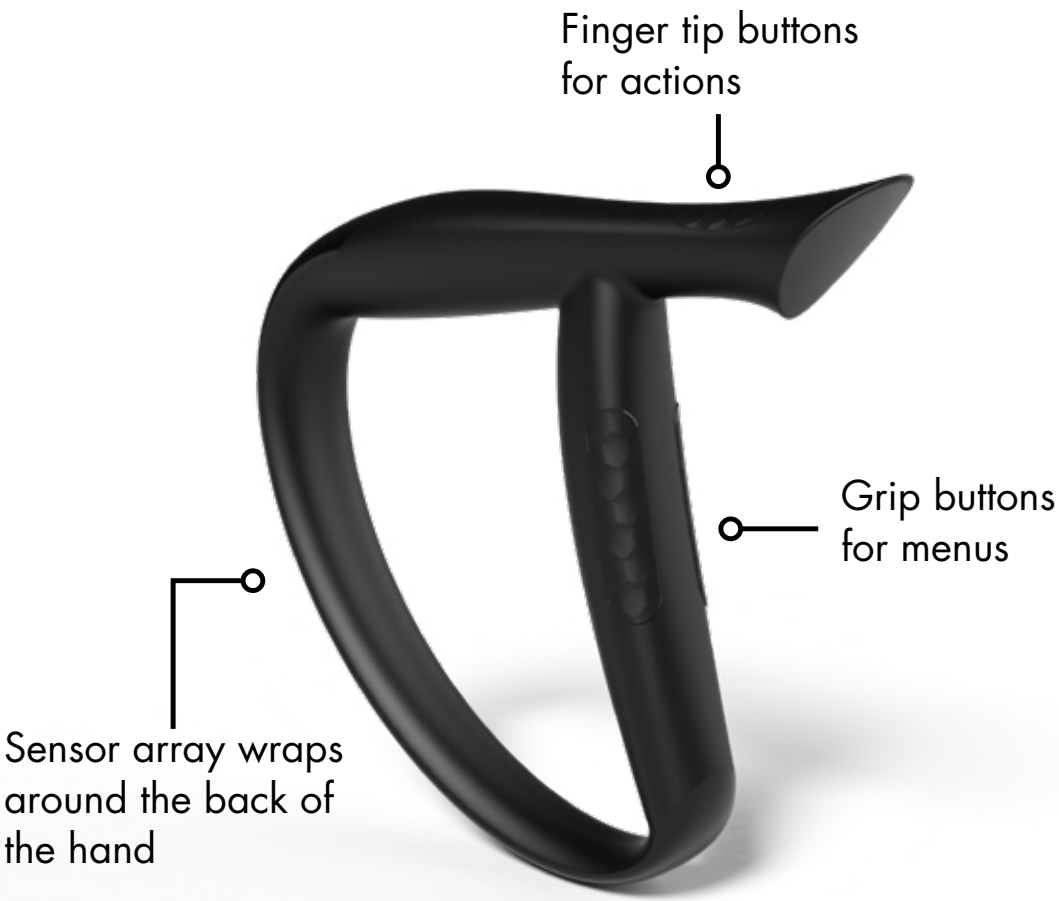
Development

Concept #1: Airbrush



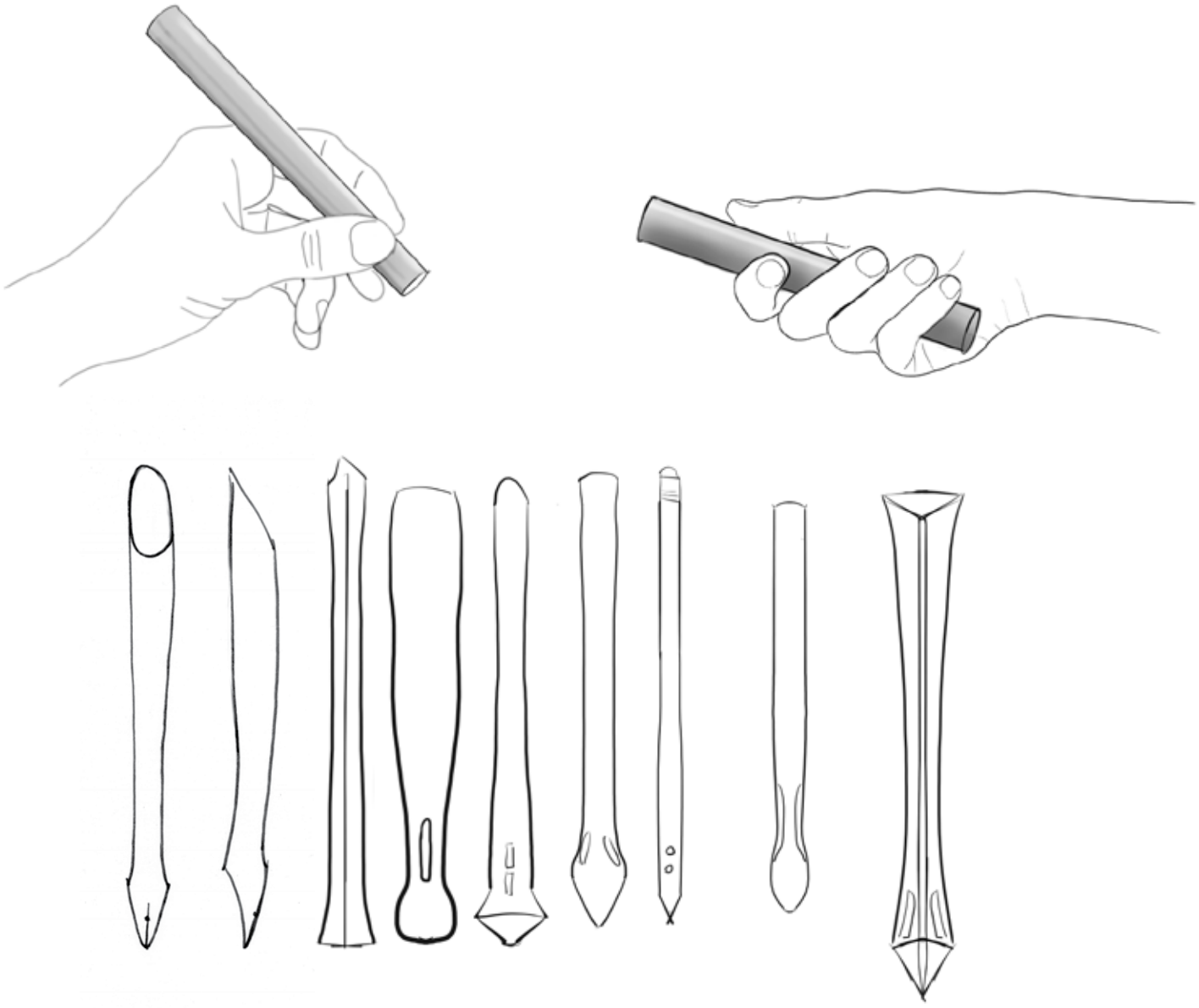


My first concept was inspired by the controls of an airbrush. It would allow for precise pointing and a solid grip in the hand. I experimented with different button and trigger configurations, including top mounted buttons, symmetrical dual buttons and grip mounted buttons.

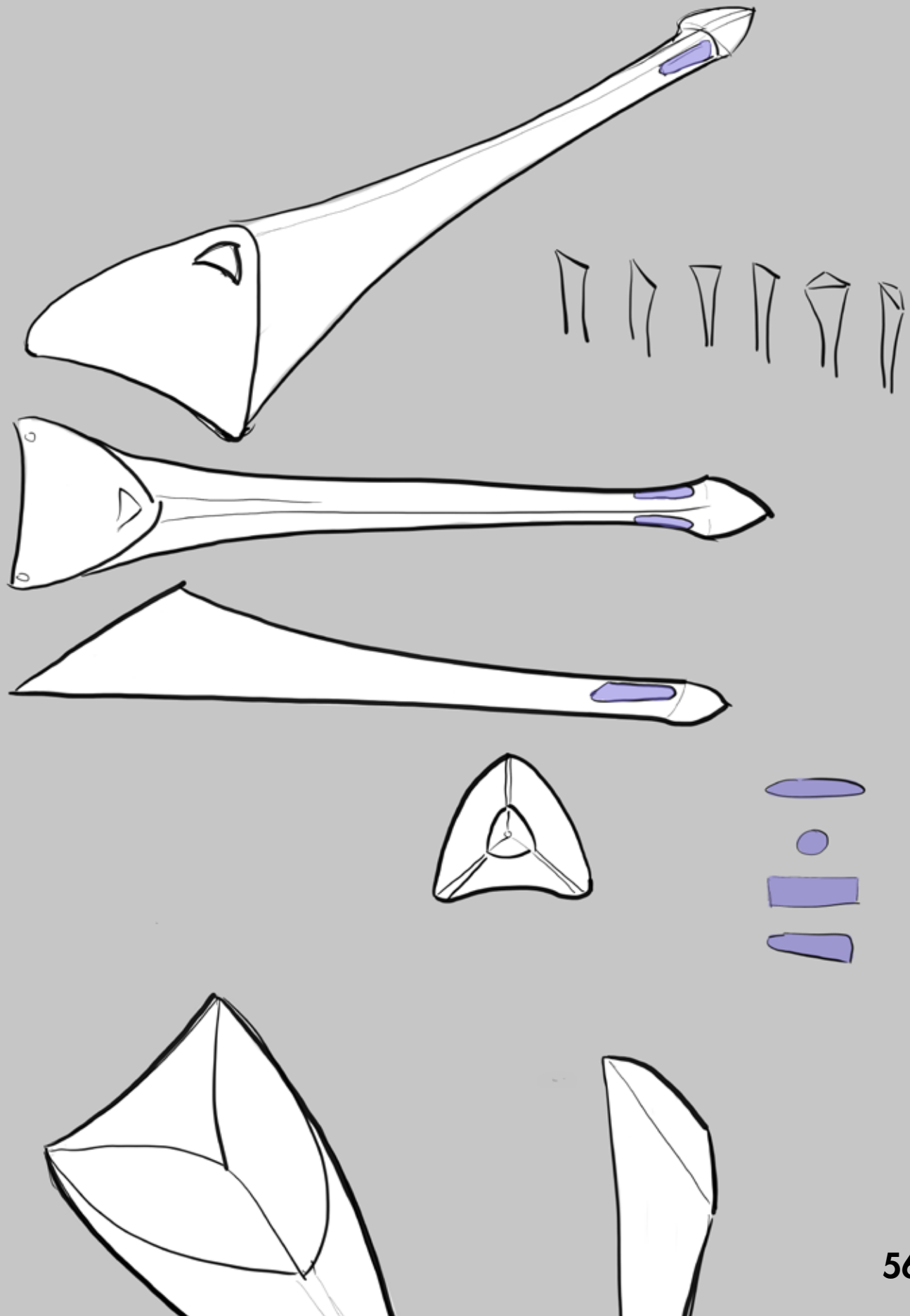


I made models of some of my sketches to test the feel in the hand, the button configurations and the proportions. I started with foam and clay, and then switched to 3D printing as I refined the concept. I received feedback saying that it was comfortable for pointing at a desk (for individual work) but uncomfortable for pointing across a distance, like one might have to do during a presentation. I knew my design needed to be comfortable for both situations.

Concept #2: Pen & Wand



With my second concept, I focused on a pointing device which could be used in two different pointing grips. I continued to experiment with button placement, while exploring grip size, and how button and sensor placements could work with different orientations of the device.

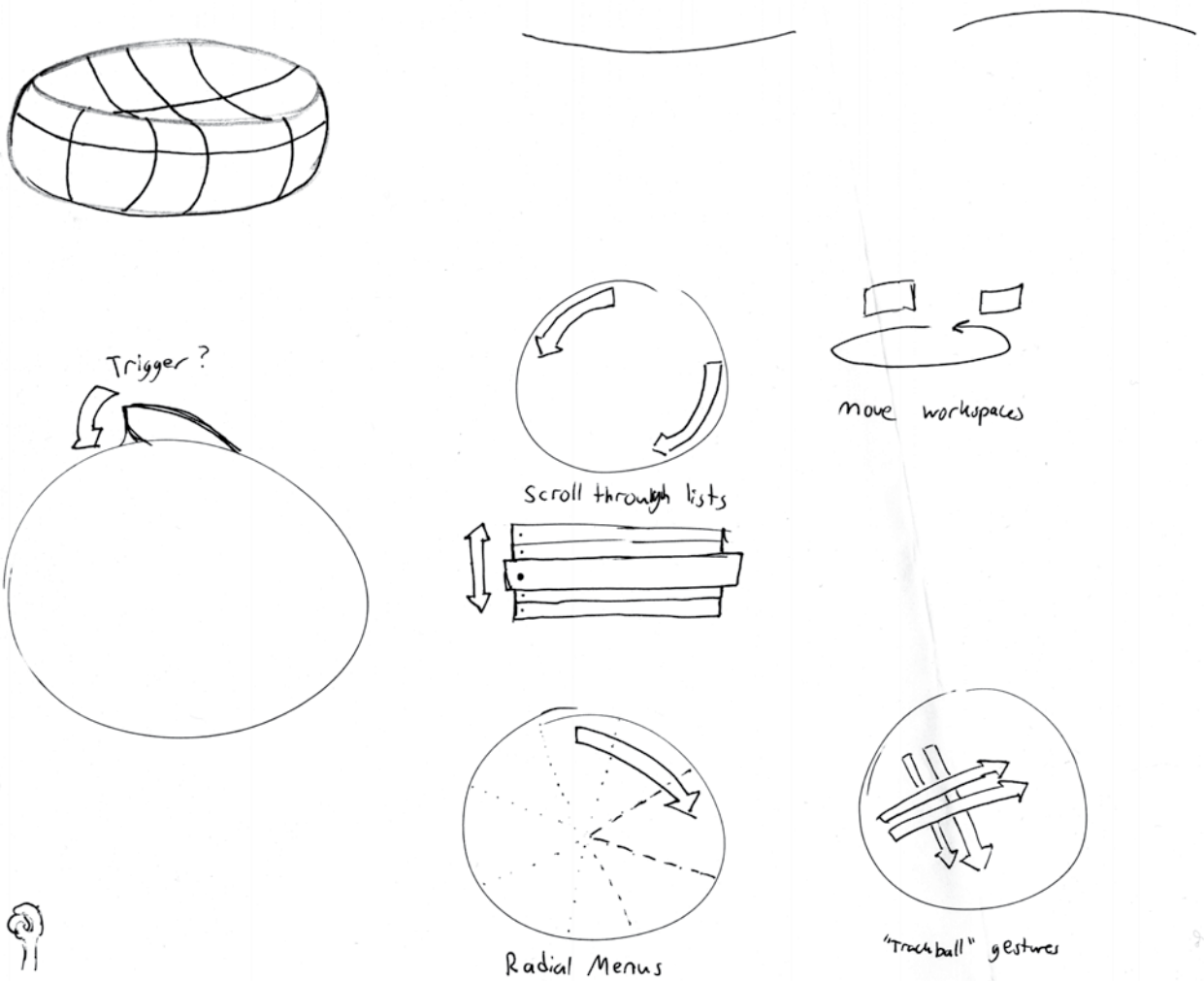


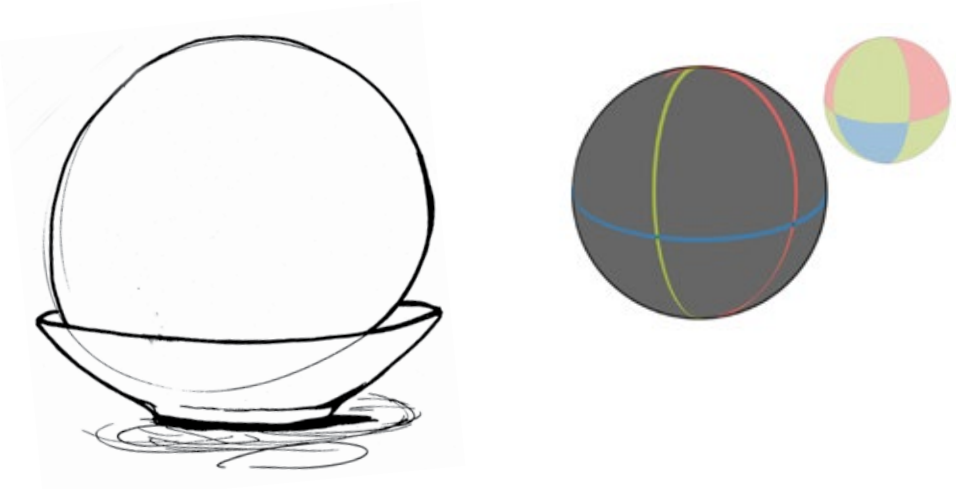
With my second concept, I focused on a pointing device which could be used in two different orientations, so that it was comfortable to use in various situations. I continued to experiment with button placement, while exploring grip size, and how button and sensor placements could work with different orientations of the device. I tested this concept with designers, having them hold and interact with my models in order to get feedback on the size and form.

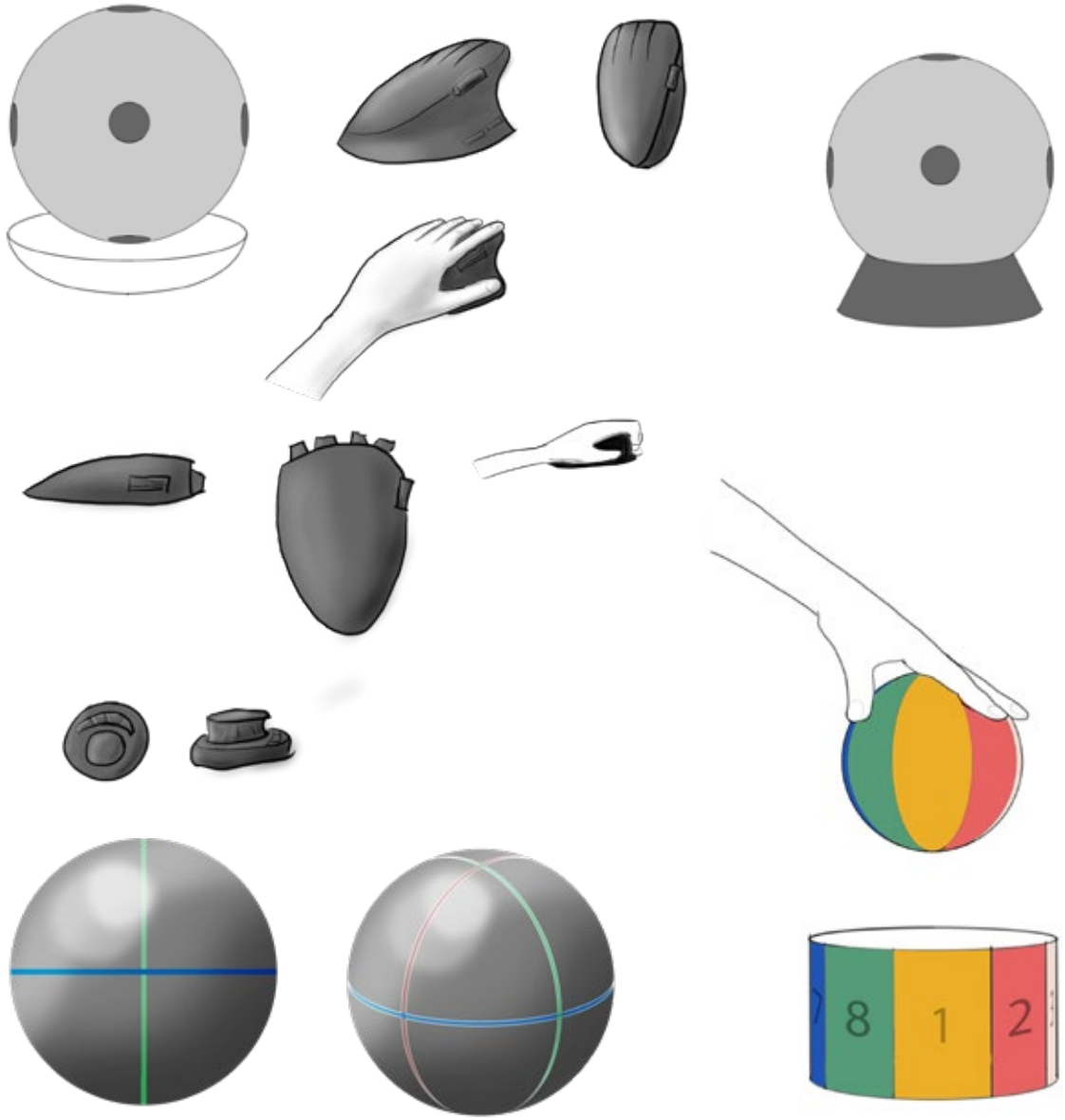
One tool isn't right for every job.

Forcing one tool to do too many jobs often dilutes the interaction and makes the tool more confusing. The mouse is used to do any motion-based job on a computer, even if it isn't suited to it. For example, the mouse is used to select tools and faces in a 3D modeling program, while also being used to orbit the object and control the camera. This results in an awkward shuffle when you need to change the camera angle while using a tool. Giving one tool and one hand multiple tasks at once is unintuitive and creates a breakdown in the workflow.

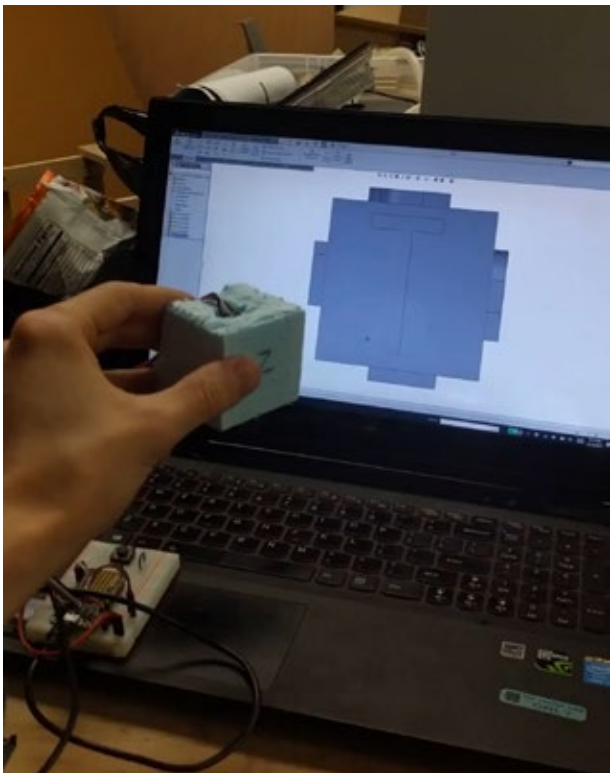
Off-Hand Control



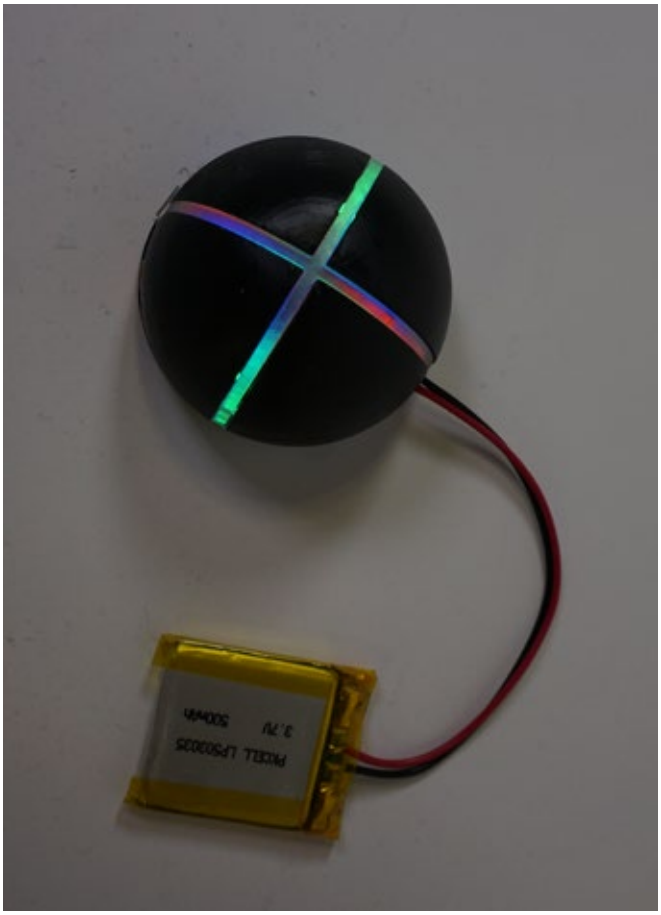




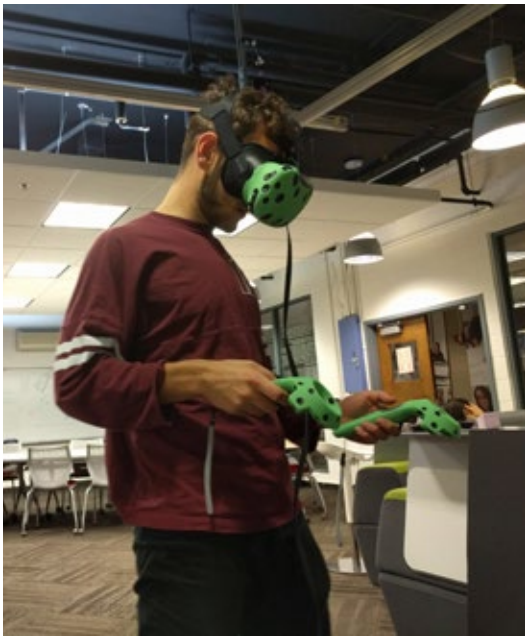
I learned from my last model that one pointing tool wouldn't be enough for all of the control you need while working in 3D space. I started to develop an off-hand tool that would allow the user to change the orientation of their model. I explored touch pads, mouse-like controllers, and 3D forms that would map directly to the model. A sphere is most suited to this control, since it can be oriented at an infinite number of angles without bias to one orientation.

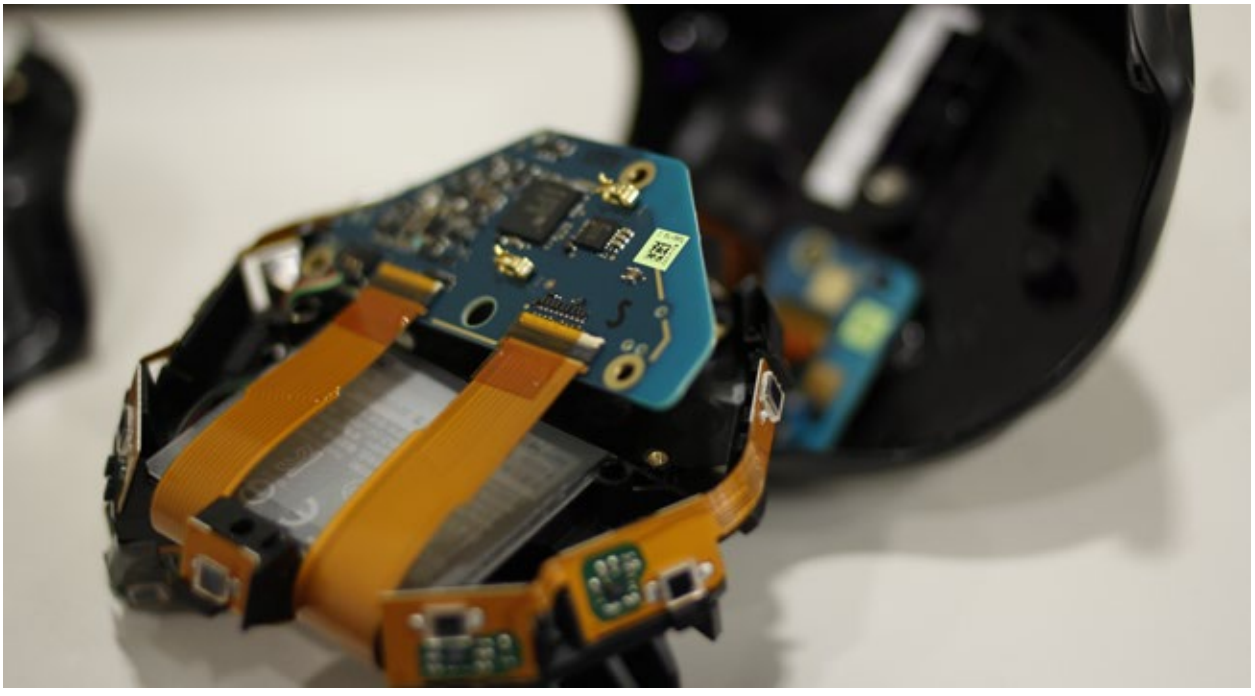


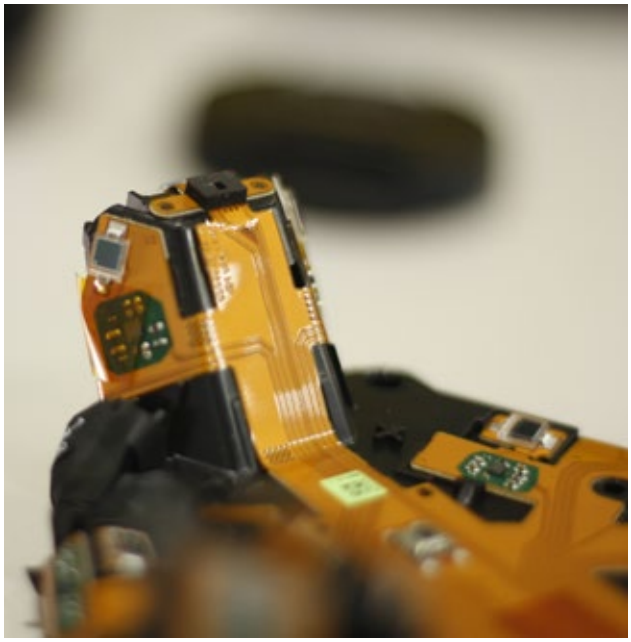
I tested the concept of a 3D trackball by making a simple prototype with Arduino, which would send commands to SOLIDWORKS as I turned the foam cube. The cube had a gyroscope inside it, measuring the orientation of the object. Testing this simple works-like model with other users showed me that the idea excited a lot of designers. They could see this being useful with their current tools, so I knew I was on the right track. Then, I prototyped different bases which would allow the user to rest the ball when not in use and make small adjustments without picking the ball up.

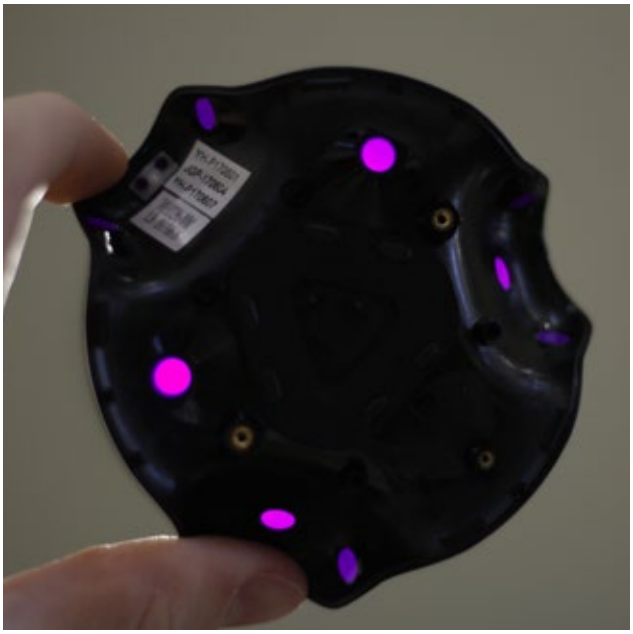


Technology Exploration





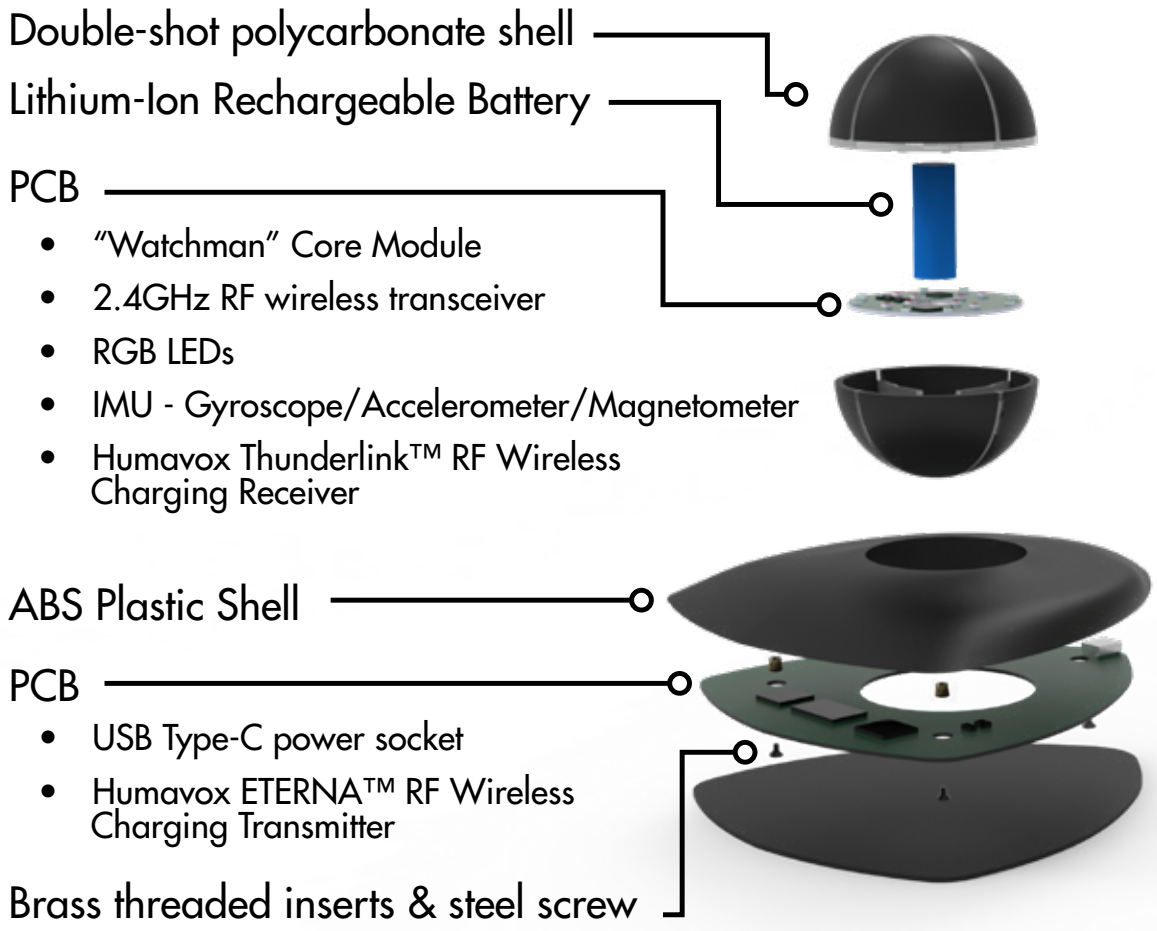


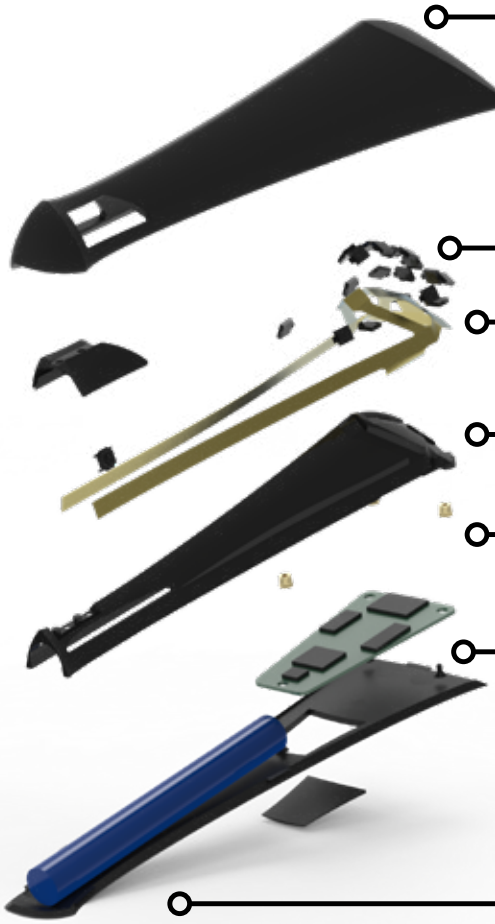


Though augmented reality technology is still in its early days, I found that the SteamVR tracking technology is the most accurate and expandable. Valve is licensing the system to other manufacturers to make controllers, and they're expanding the technology to include support for large spaces, like homes and offices. To explore the feasibility of my design, I based my concept on the SteamVR tracking technology. I took apart the Vive tracker, a 3D trackable accessory made by Valve, to better understand the way that Valve manufactures its controllers. They use flexible PCBs wrapped around an internal structure to orient the optical sensors in various directions all across the surface of the part. The outer shell is made of a polycarbonate which is tinted to block out all light except for the IR spectrum. The tracker also uses the specially designed "Watchman" core processor.

Exploded View

Utilizing SteamVR Tracking Technology





IR transparent polycarbonate shell

TS3633 Photodiode Array

Flexible PCB

Internal electronics support

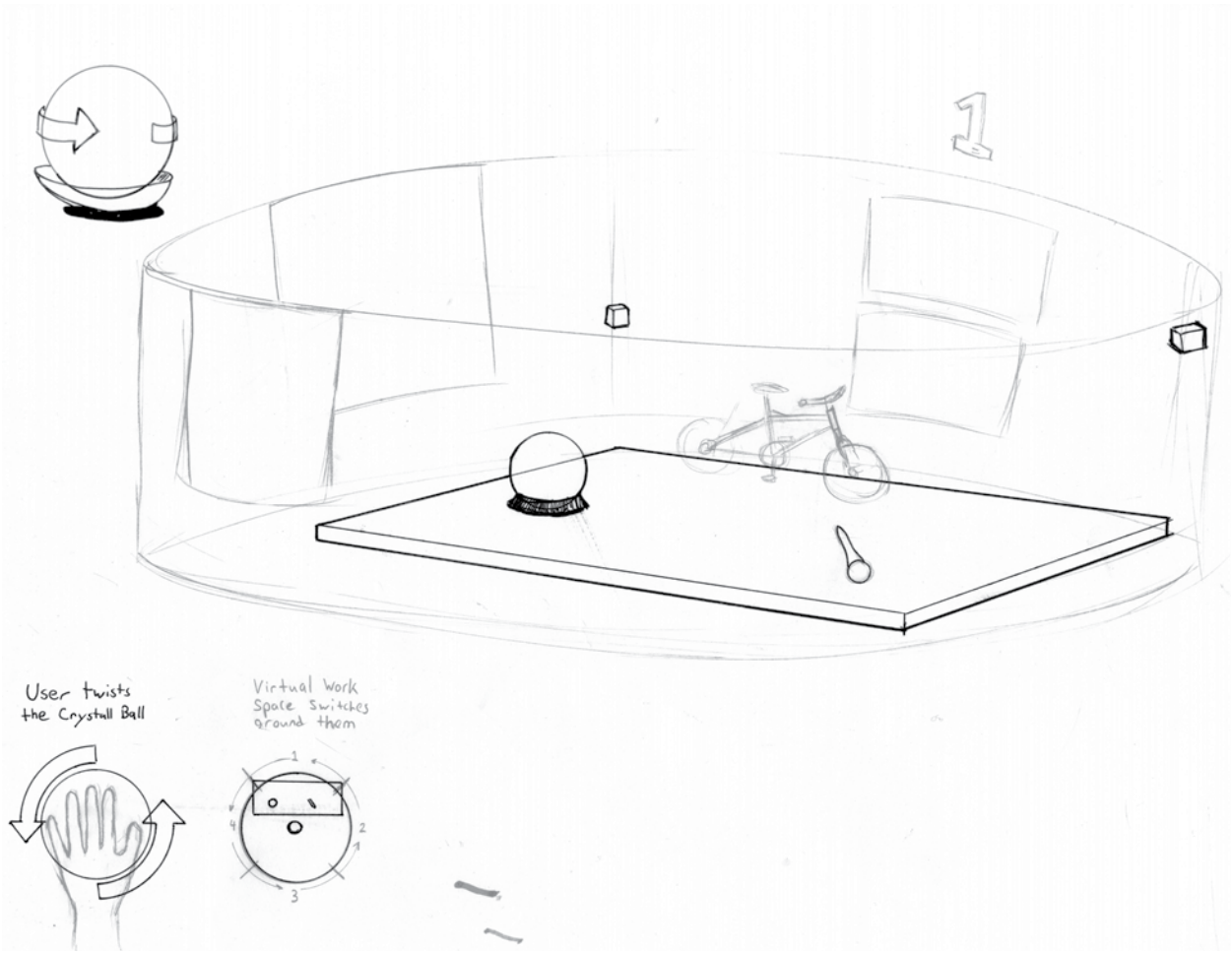
Brass threaded inserts &
steel screw

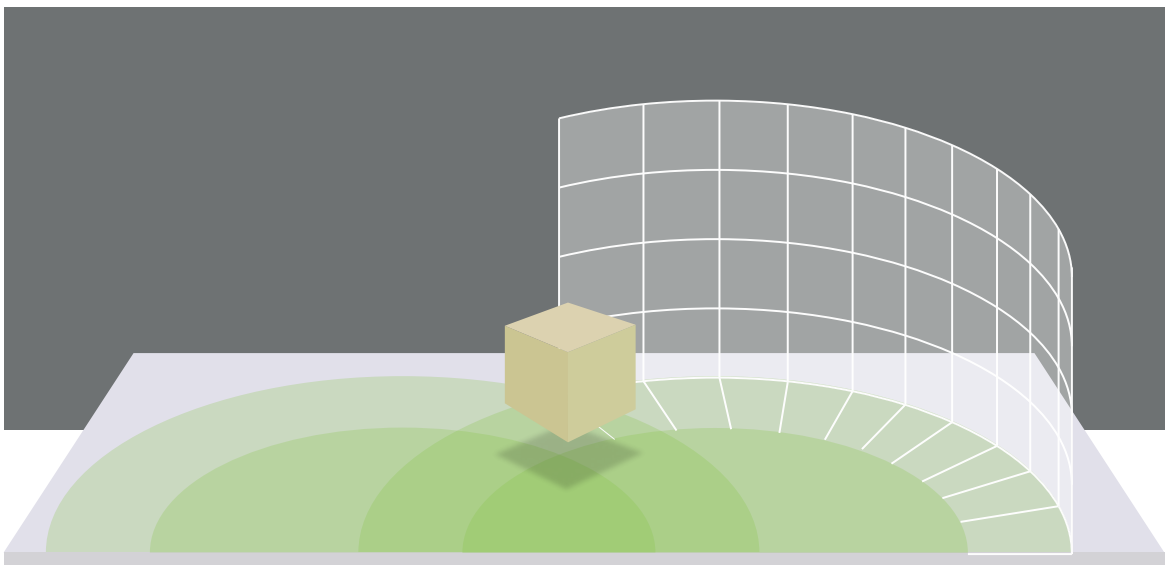
PCB

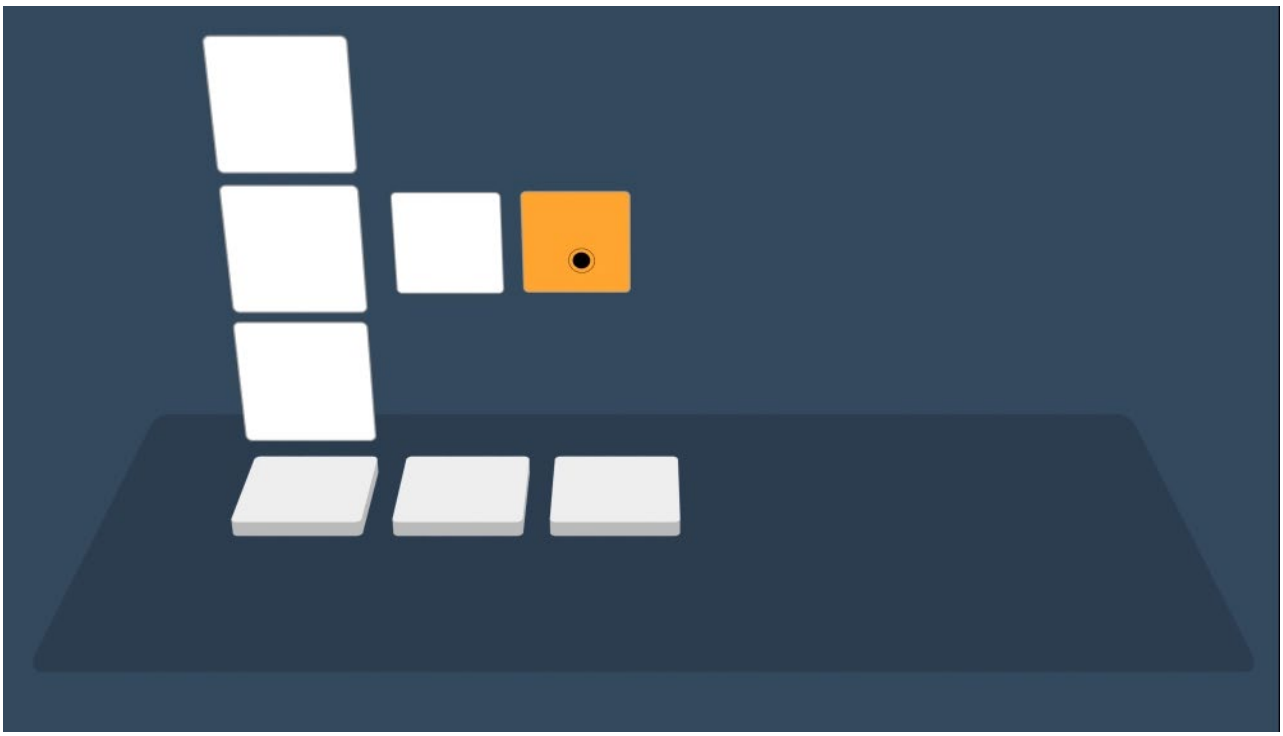
- "Watchman" Core Module
- 2.4GHz RF wireless transceiver
- IMU (Inertial Measurement Unit)
- TS4233 Light-to-Digital Converters
- Humavox Thunderlink™ RF Wireless Charging Receiver

Lithium-Ion Rechargeable Battery

UI Sketches and Mock-ups







In this system, the design of the physical tools is directly linked to the user interface and the virtual interactions. I explored different ways of building models, displaying information, and accessing settings. I sketched and then mocked up some examples using Adobe After Effects and A-Frame, a webVR framework to test my concepts with users.

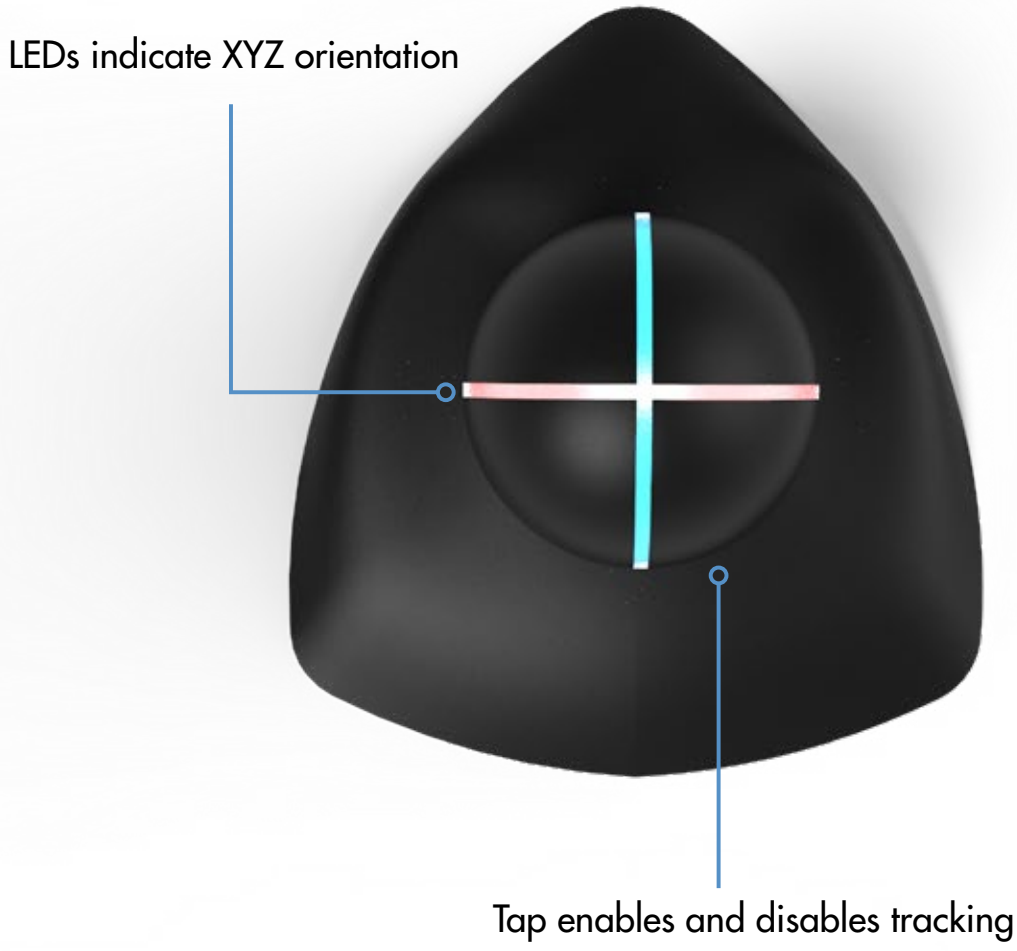
The information in your line of sight will always command the most attention, but relevant, less immediate information can be placed in the peripheral.

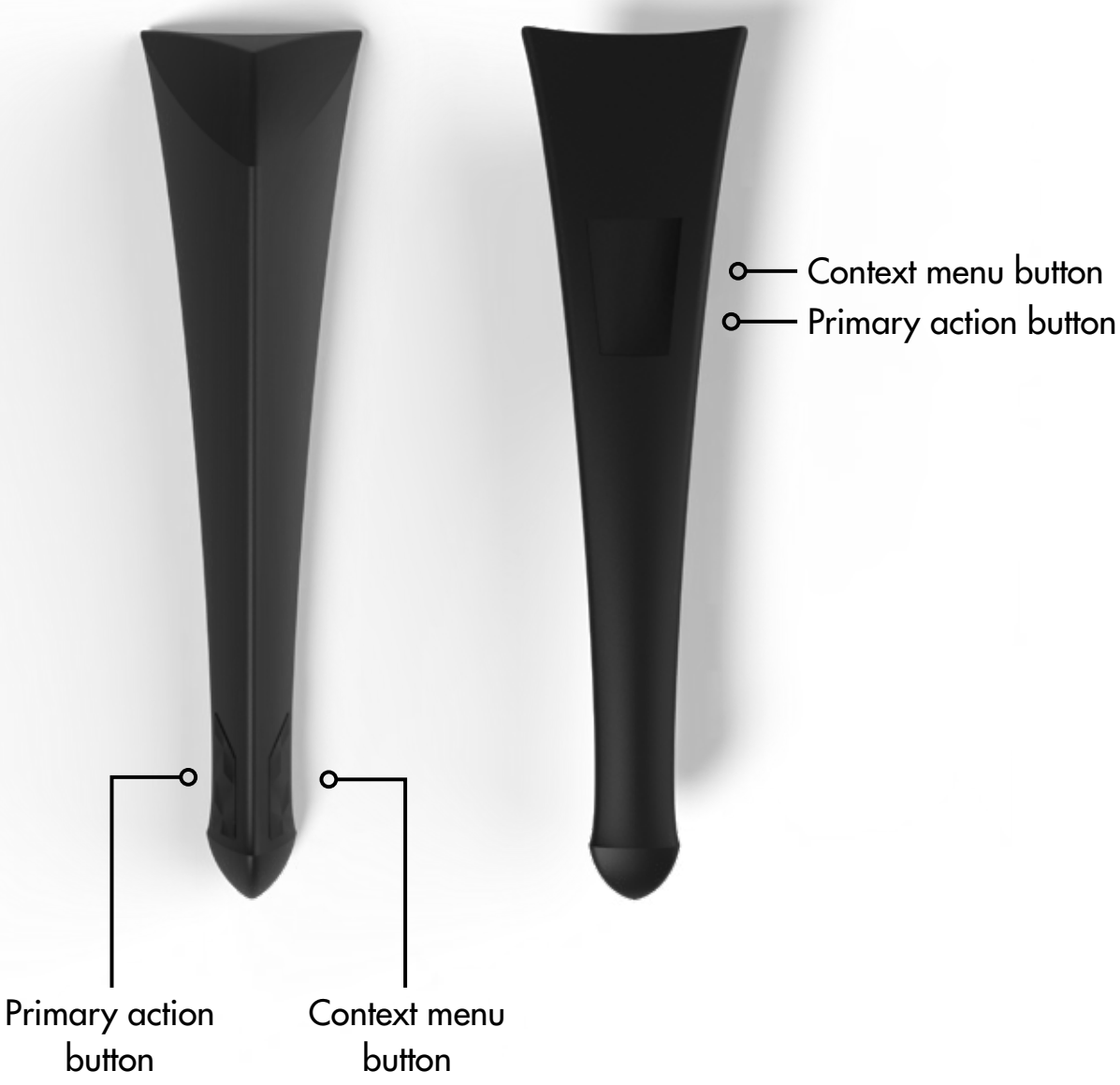
With the flat screens that we are used to, all of our windows, tool bars, and information have to share the same space. Without the limitations of those 2D screens, information could be placed in different places depending on its importance or relevance to the current task. I explored menu and UI concepts which keep the most important information visible but out of the way and bring important settings right to your fingertips when you need them. This keeps the work space from getting cluttered, while providing access to important controls and information when they are needed.

4

Final Design

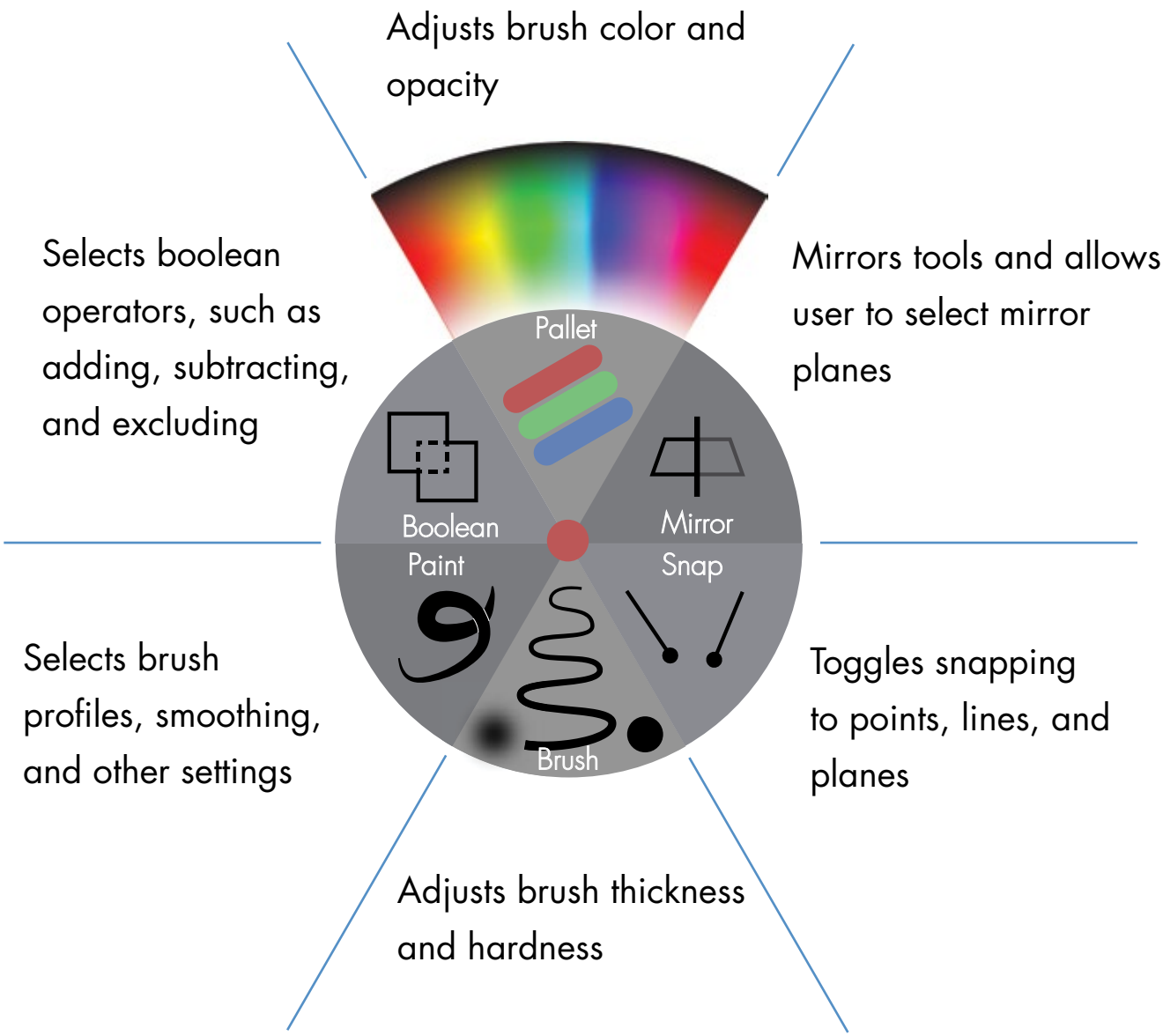
Buttons and Interaction points



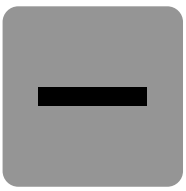

Context menu button
Primary action button
Primary action button
Context menu button

Reuleaux UI

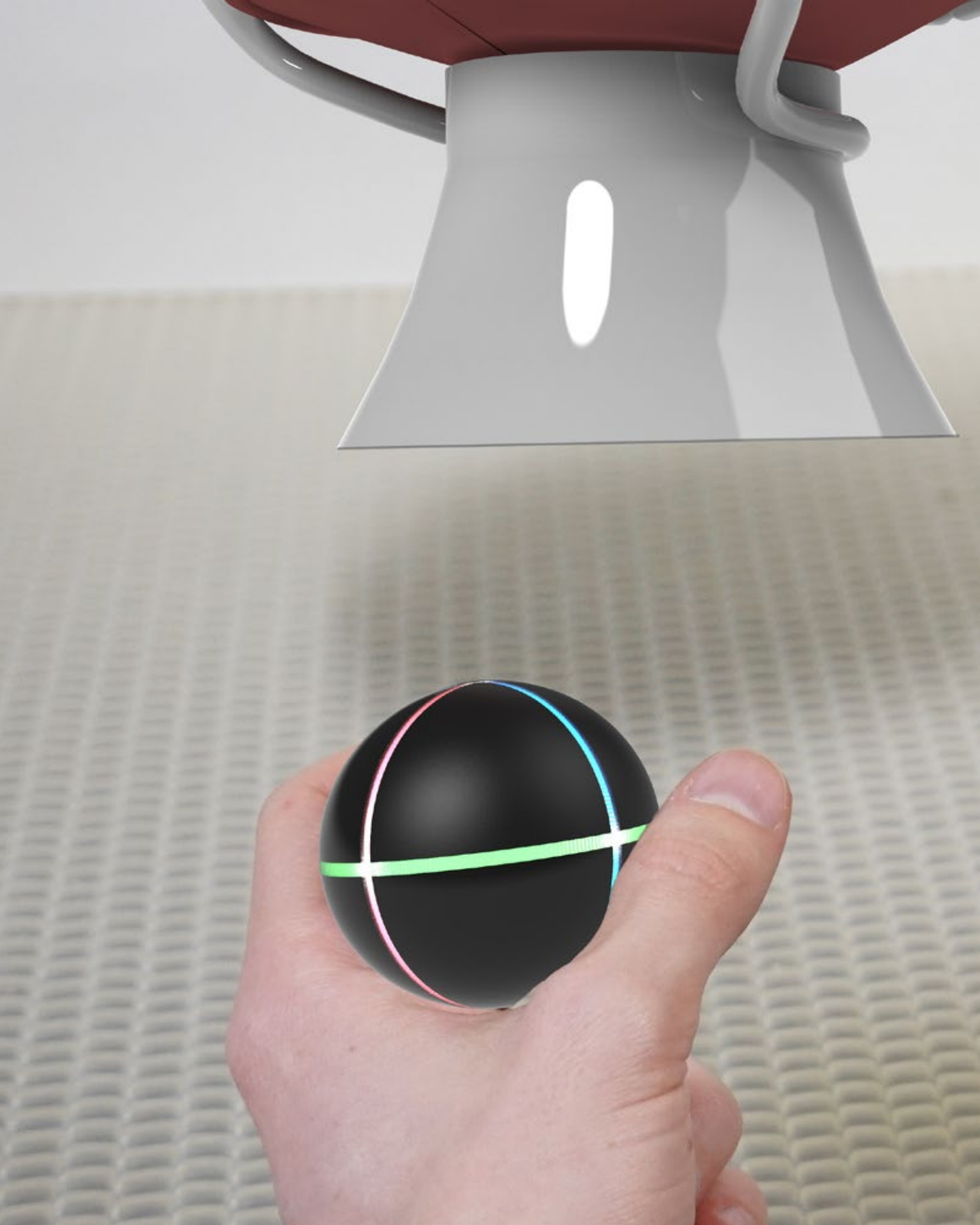
Radial menus allow for quick access to relevant settings. They are opened by the menu button on the pen, and appear directly in front of the user. As the user moves their pen out from the center, each menu item expands to show more controls relevant to that setting.



Desktop menus allow for switching modes and accessing less commonly used settings

 Measure	Measures real and virtual objects and reference measurements later.
 Revolve	Creates faces or solids which revolve around a central axis.
 Select	Selects objects, shapes, and faces to move, change settings, delete, or group them.
 Paint	Draws in 3D space, with variable brush sizes, colors, and shapes.
 Primative	Creates rectangular prisms, cylinders, cones, spheres, and other primitive 3D objects.
	Minimize menu


Desktop menus stays
out of the way, while
still being within reach



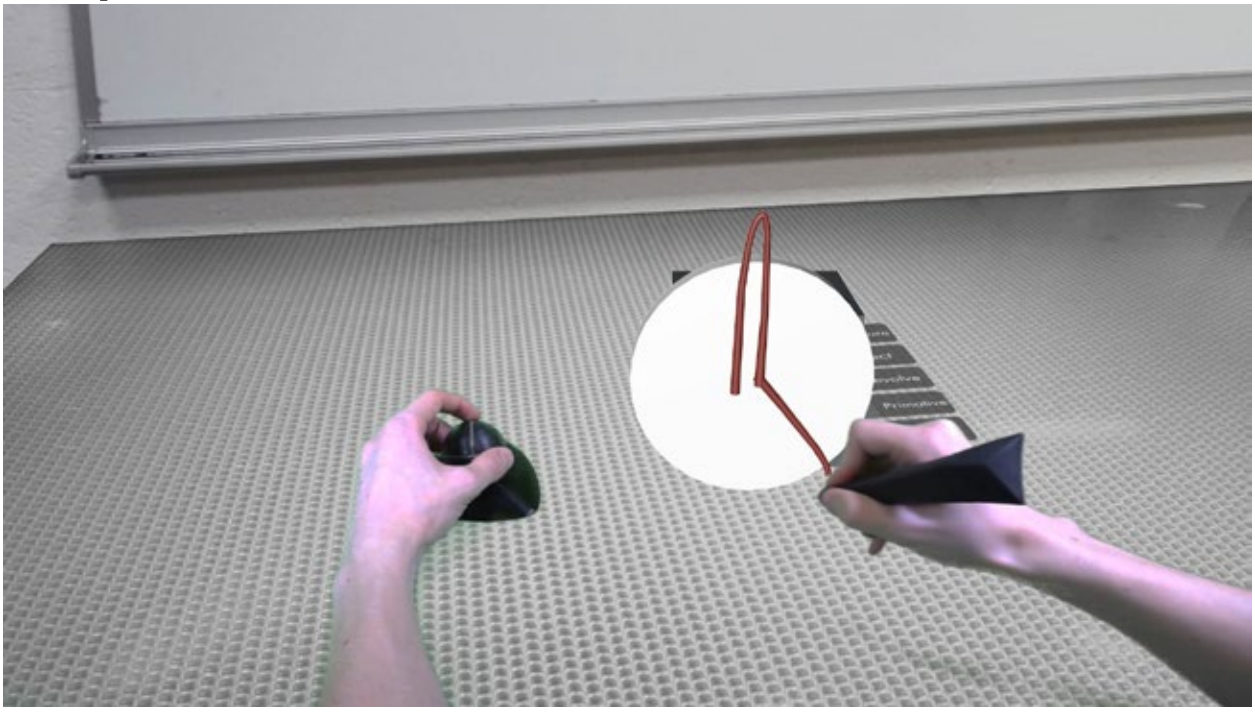
Context menus appear right at your finger tips and disappear when you're finished with them.

Conditions for Success

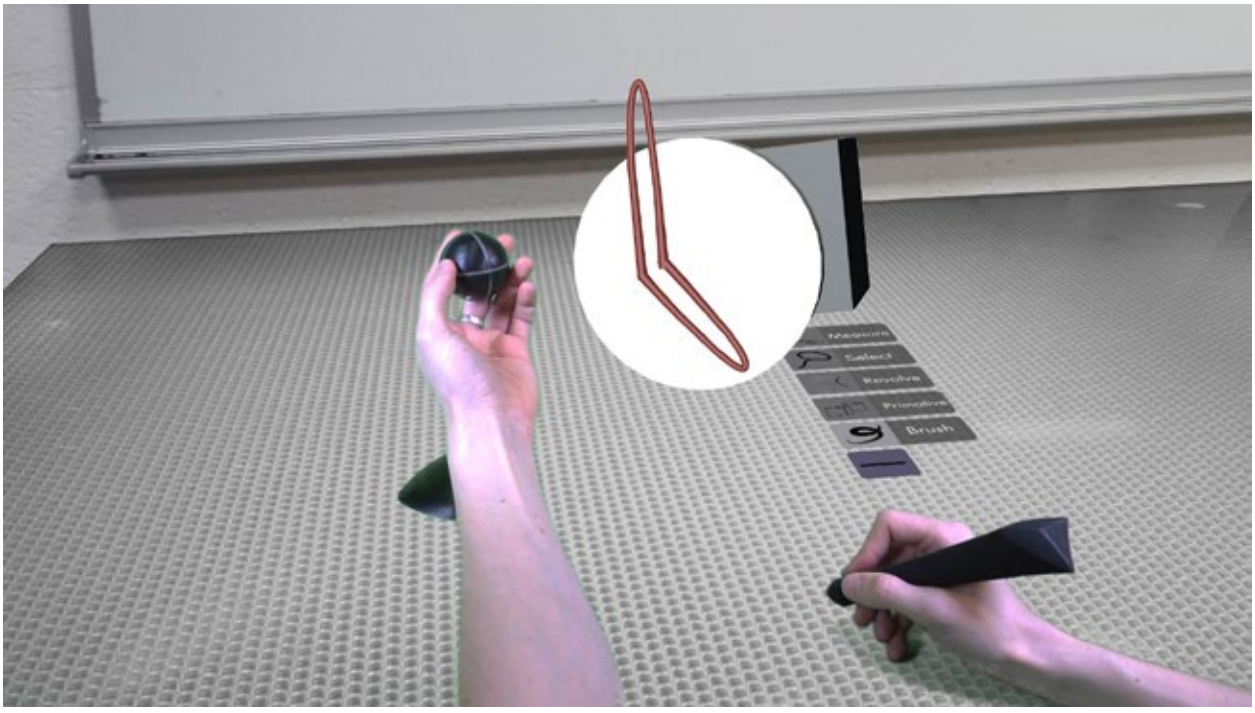
Why use Reuleaux?

- Rapid creation of 3D sketches and models
- Accurate scale and proportion in 3D
- Demonstration of interaction and functionality
- Rapid iteration and collaboration by seamlessly duplicating and sharing models
- Independent, simultaneous control of model orientation and virtual tools
- Easily fix or undo mistakes
- Practical for individual, collaborative, and demonstrative scenarios

Independent



Rapid creation of 3D sketches and models



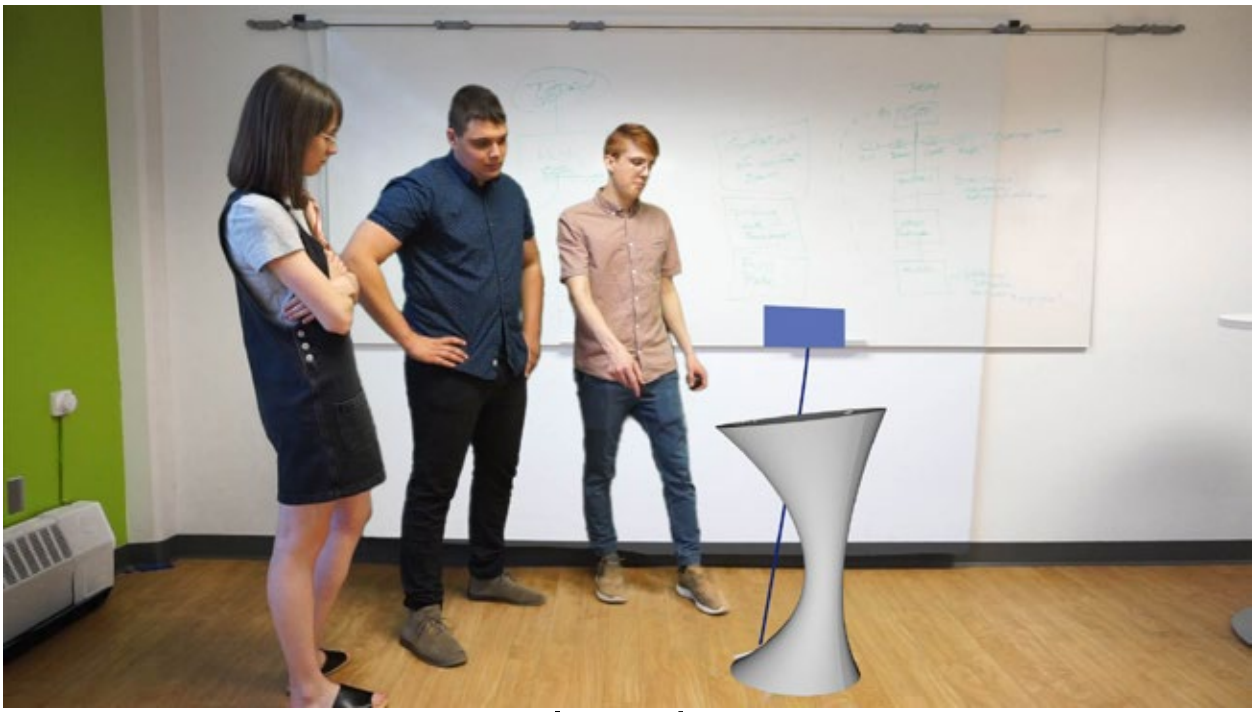
Independent, simultaneous control of model orientation and virtual tools

Collaboration

Enables mistakes to be easily fixed or undone

Rapid iteration and collaboration

Demonstration



Demonstrate accurate scale and proportion in 3D

Demonstrate interaction and functionality of models

Thank You

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I couldn’t have done this on my own!