Next Generation of Simulation: VR / AR

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STRATUS
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About Me

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Background:

- System Engineering
- Human Factors
- Human-Computer Interaction
- XR Development

Human Factors & Cognitive Engineering Lab

STRATUS Center for Medical Simulation

Harvard Medical School

Mass General Brigham

Translational Research Institute for Space Health

NIH National Institute of Mental Health

NSF I-Corps

Today!

Today!

Simulation → XR Foundation → XR Design Process → VR Use Cases → AR Use Cases

1-hour	1-hour	1-hour
9:00 – 10:00	10:10 – 11:10	11:20 – 12:30

- Part of data presented here including videos, figures, and tables are from the following funded projects:
    - DoD grant
    - NASA TRISH grant

- Some figures are unpublished. Please do not disseminate. Thank you!

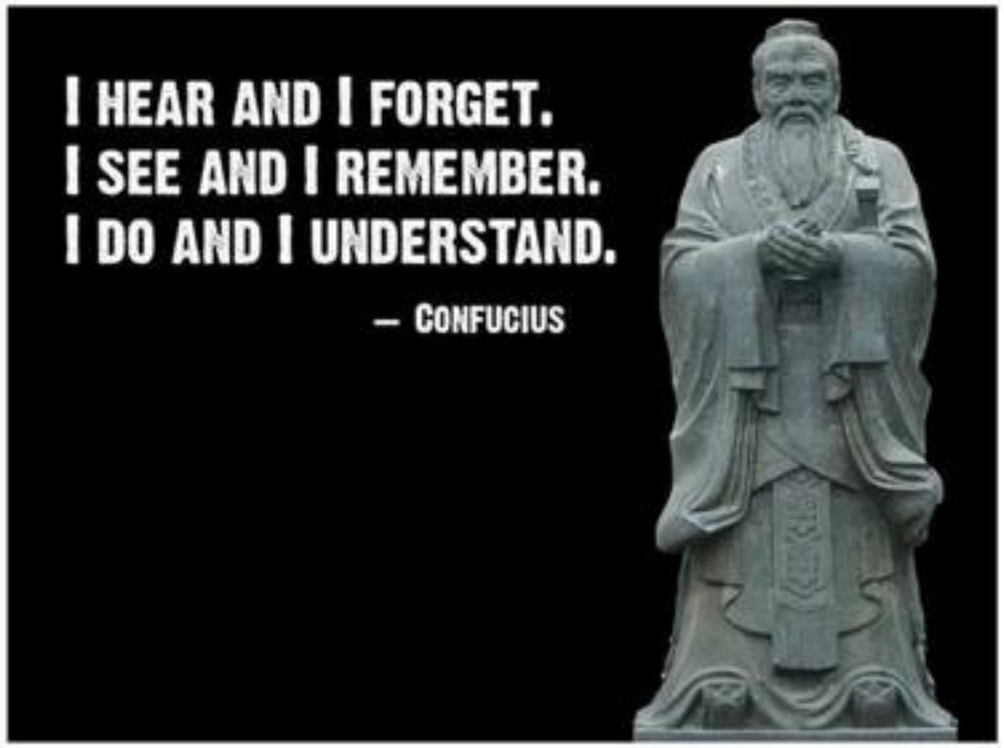
Learning Objectives

Getting familiar with the following topics:

- XR **foundations**: What is XR, VR, AR?
- How **XR design process** look like?
- What is **360 videos** and how to use them?
- What are **XR development platforms** (Unity vs Unreal vs Web 3D)?
- How to create **3D models** for scenarios? Where to get them?
- How to create **human models** and animations for scenarios?
- How to capture **human body, face, and hand motion**?
- What are XR design **challenges**?
- What are **use cases** of VR and VR in Healthcare, Transportation, Space, and Military?

Part 1

Why Simulation?


I HEAR AND I FORGET.
I SEE AND I REMEMBER.
I DO AND I UNDERSTAND.
— CONFUCIUS


See
Hear
Do
+
+
Remember

Simulation is a **technique** – not a technology – to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real word in a fully interactive manner.

Gaba DM. The future vision of simulation in healthcare. Qual Saf Health Care 2004;13i2-i10

Not a New Idea!



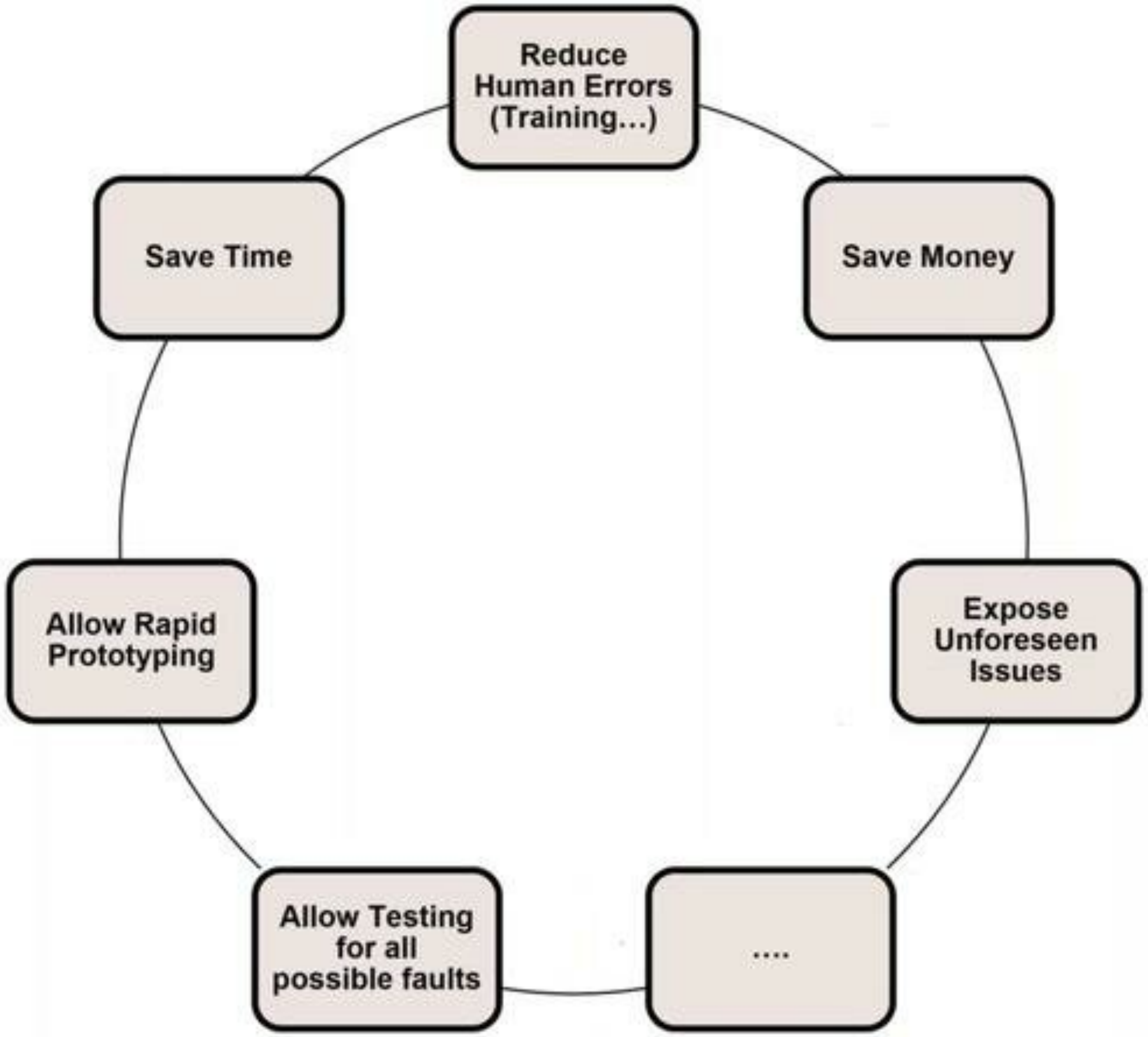




https://journals.lww.com/md-journal/Fulltext/2022/06240/A_review_on_the_evolution_of_simulation_based.46.aspx

Applications

Why Simulation?



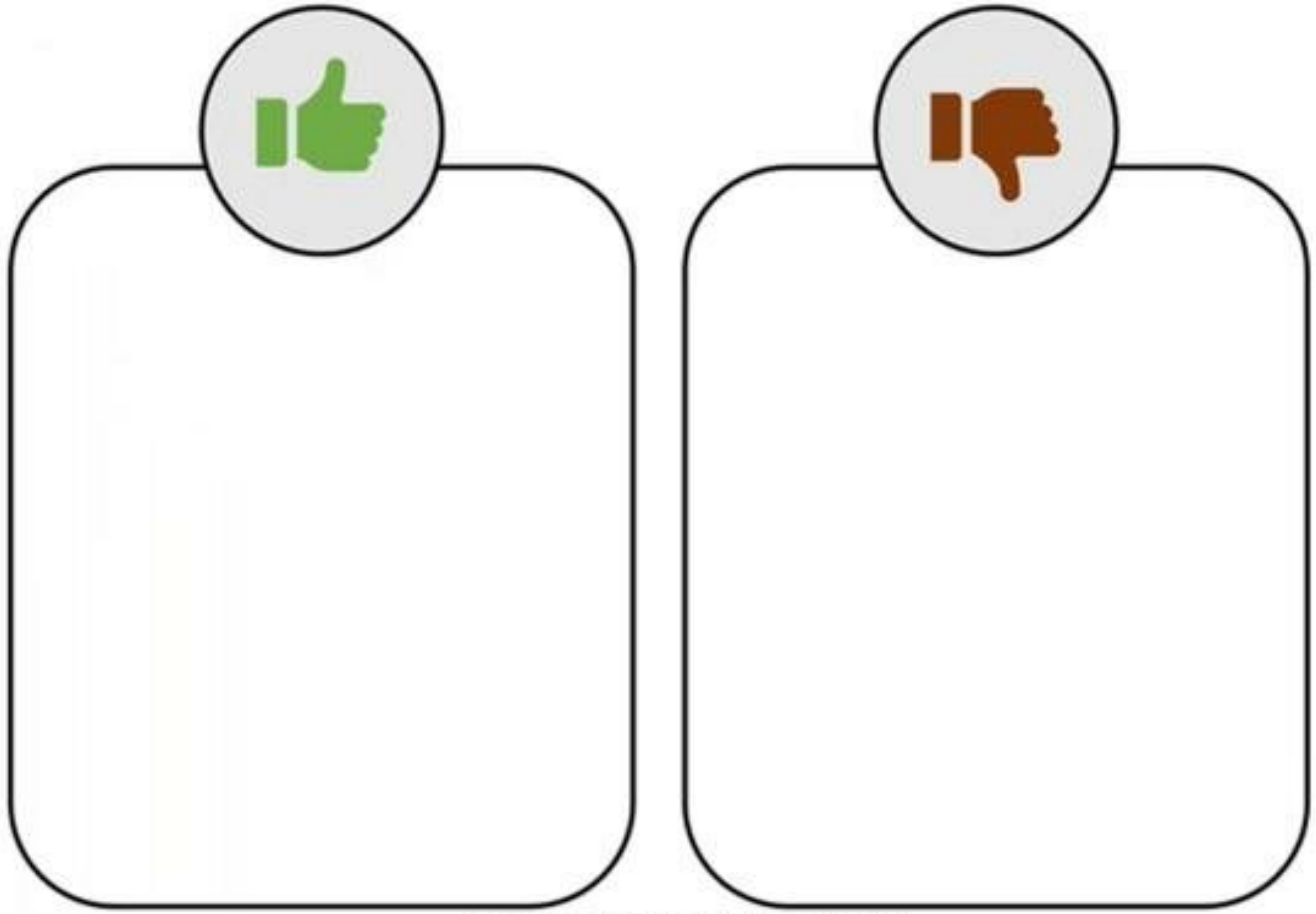
Issues

Cost	Space	Staffs	Maintenance
Fixed (no update)	Limited Scenarios	Limited Interactivity	...

Can XR Help?

[“it depends”]

E.g., Pros and Cons of XR in Healthcare:



E.g., Pros and Cons of XR in Healthcare:

- Improved flexibility and customisation options
- Can be applied in numerous healthcare areas
- Fun and psychologically safe learning environment.
- Provides detailed 3D images

- High cost of equipment and software
- Could be addictive
- May disorient users who are more susceptible to such effects
- Lack of extensive trials and use history
- Limited use in practicing patient communication

Btw, What is XR?

Part 2

XR Foundation

VR (Virtual Reality)

AR (Augmented Reality)

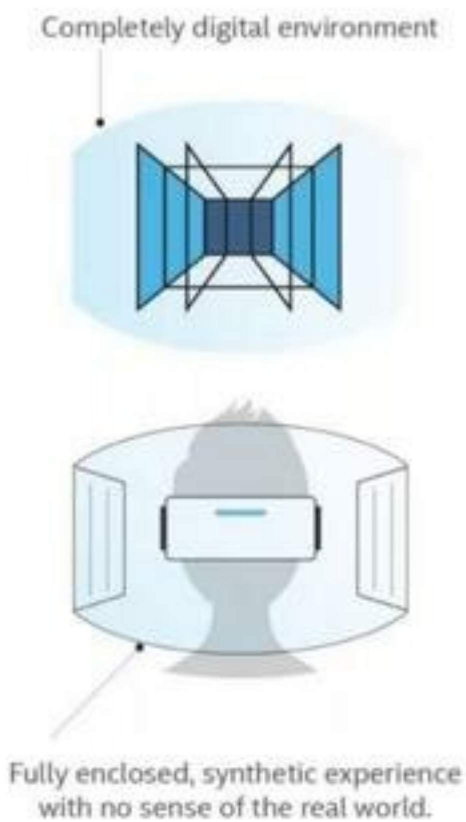
MR (Mixed Reality)

XR (Extended Reality)

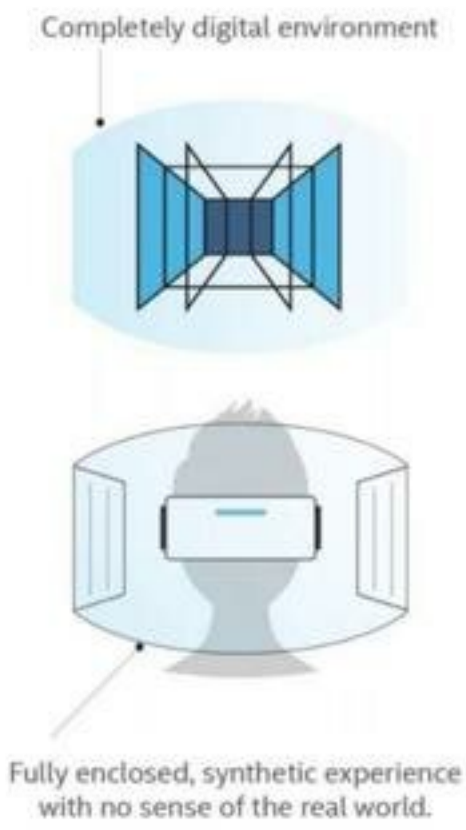
XR (Extended Reality)

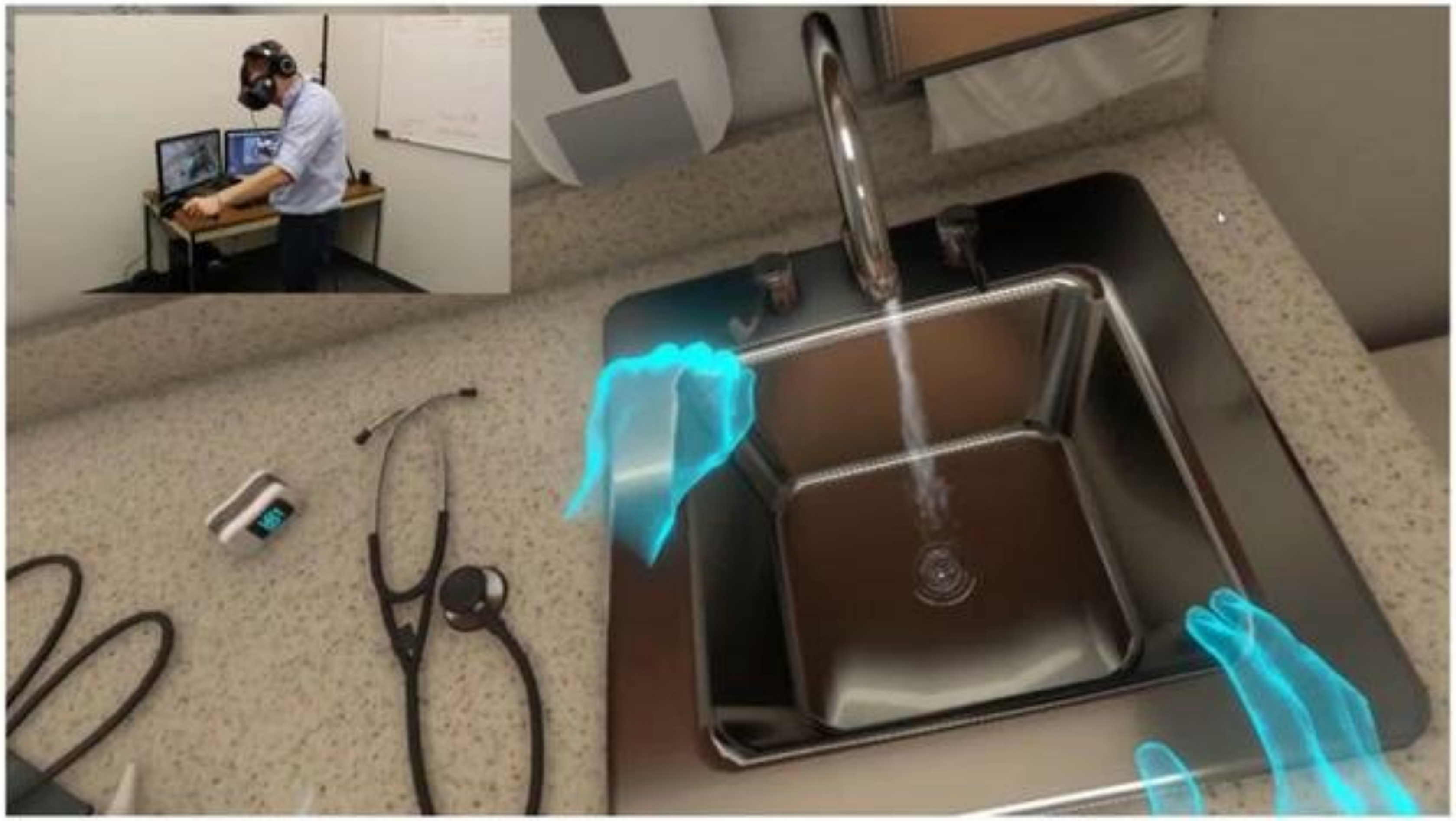
VR (Virtual Reality) AR (Augmented Reality) MR (Mixed Reality)

VR: Virtual Reality

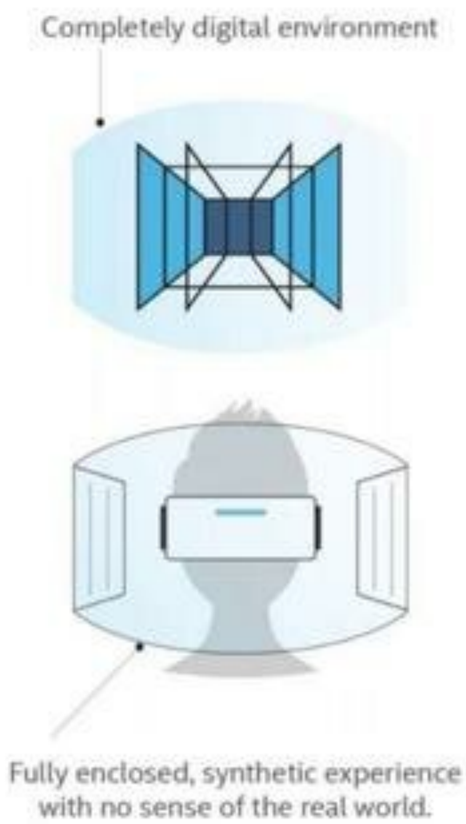


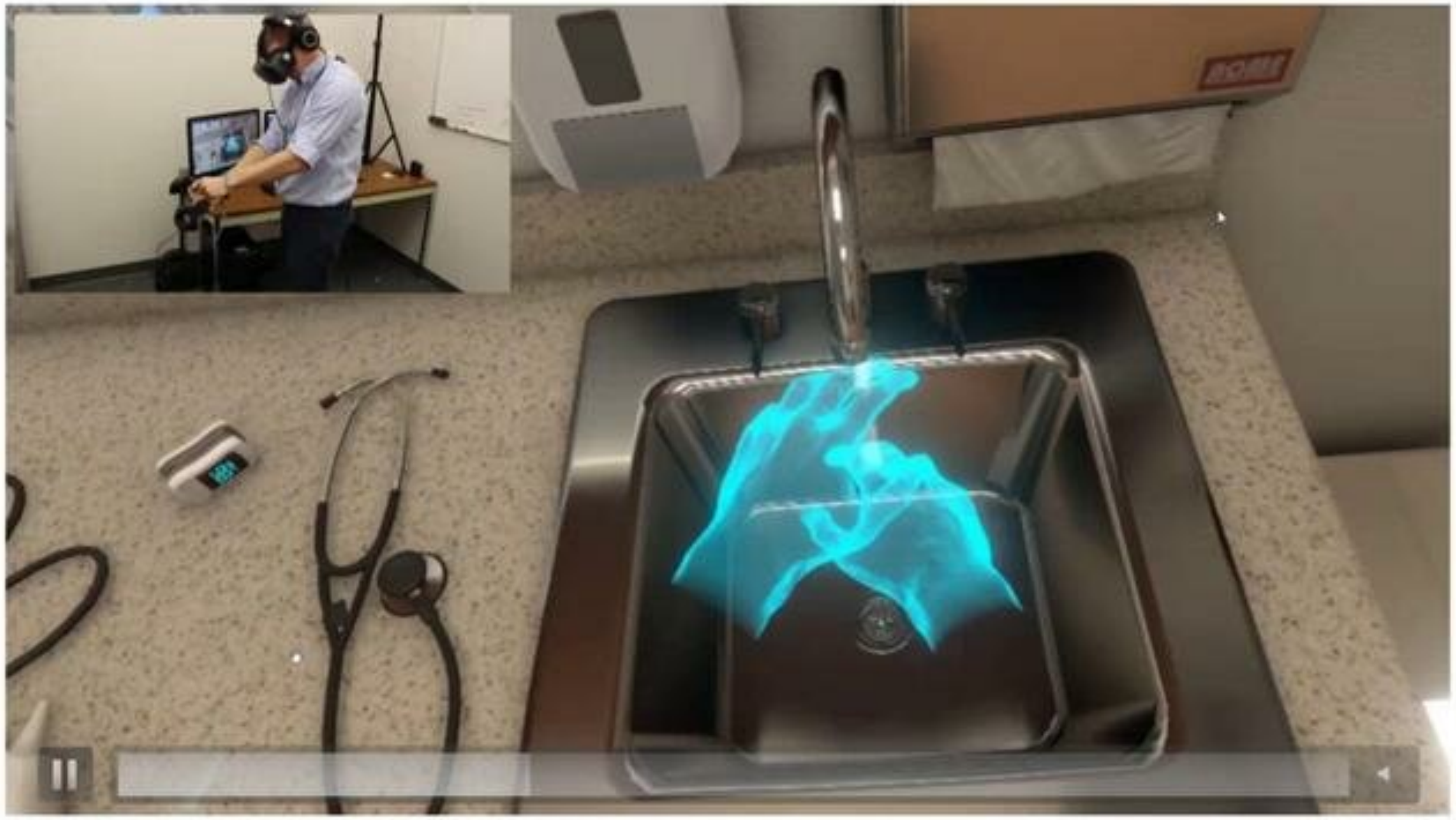
VR: Virtual Reality



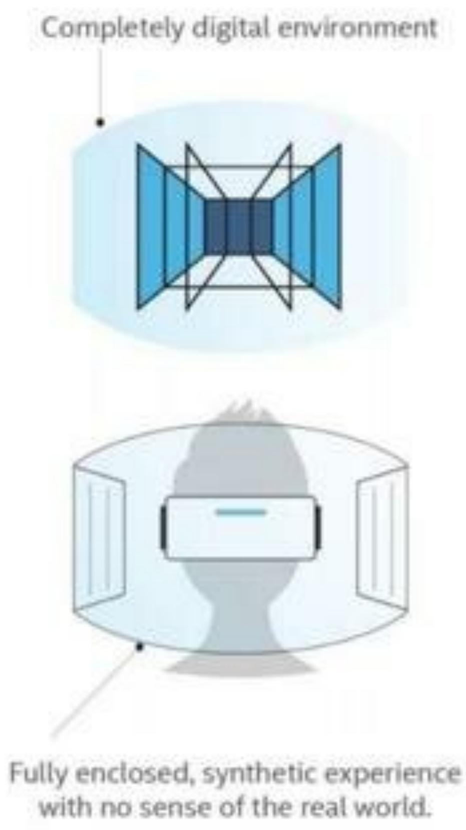


VR: Virtual Reality

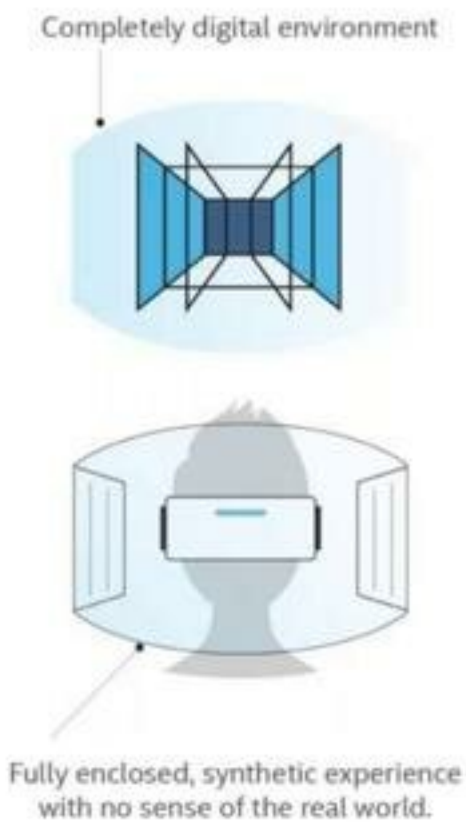


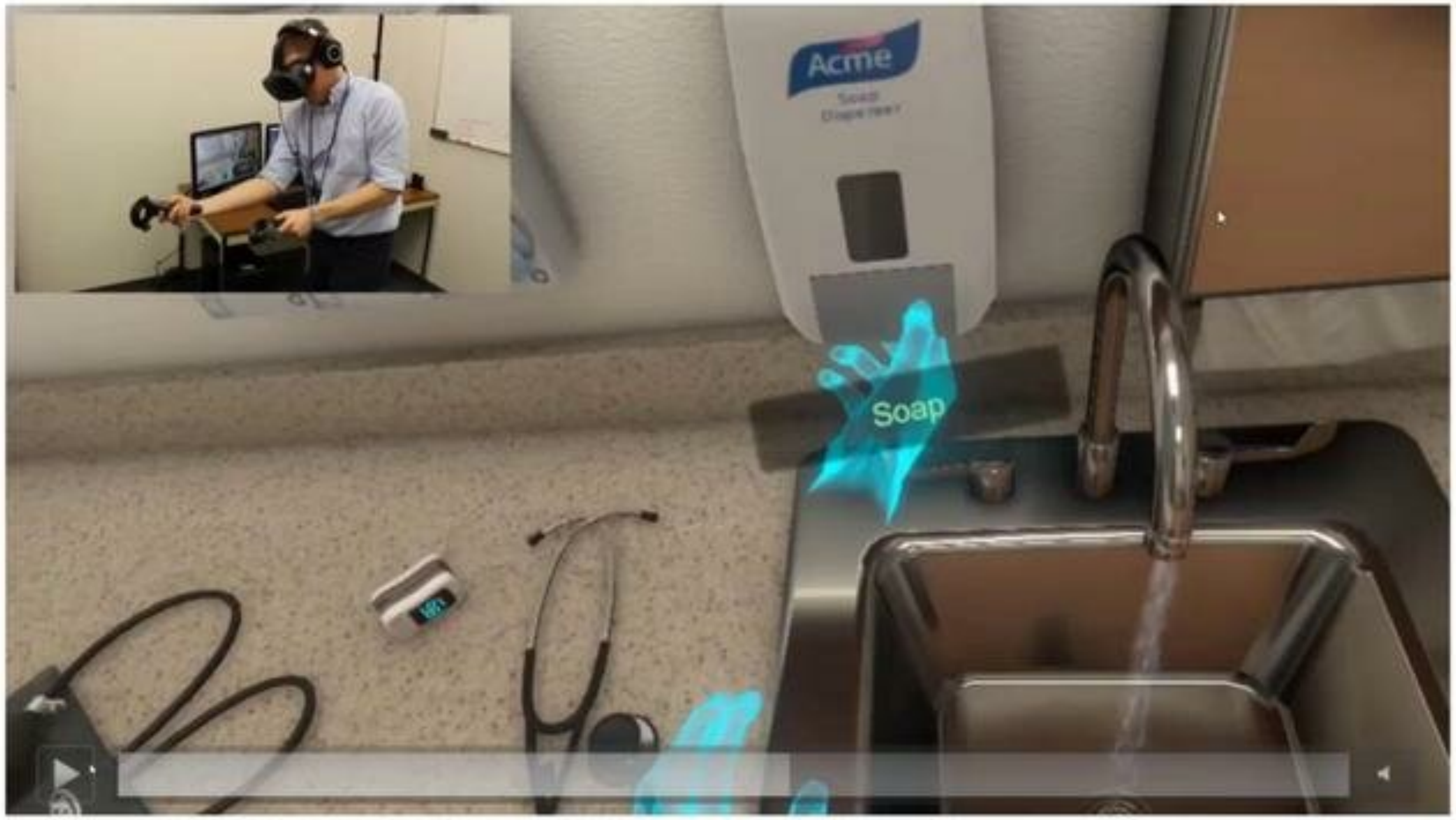


VR: Virtual Reality



VR: Virtual Reality





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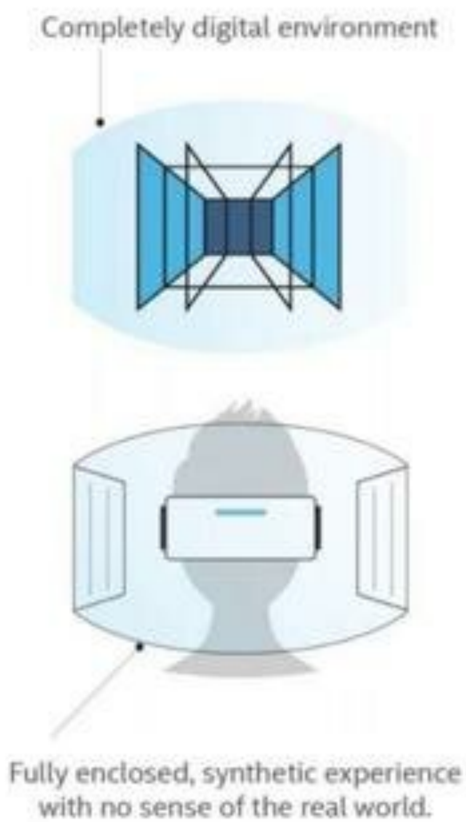

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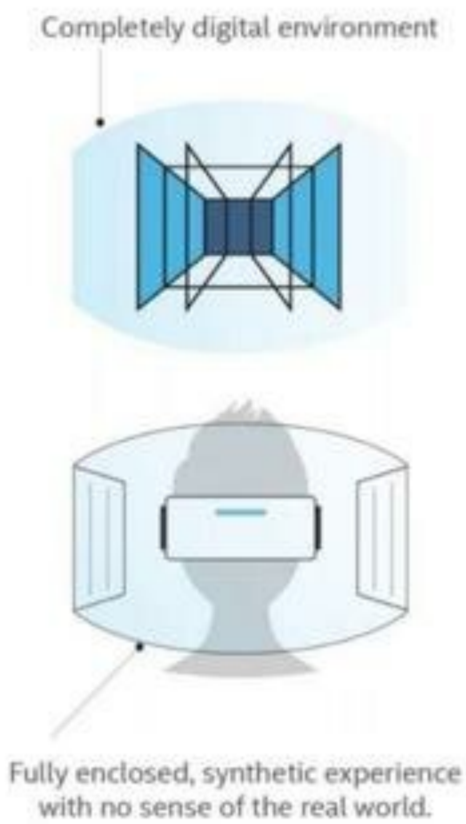

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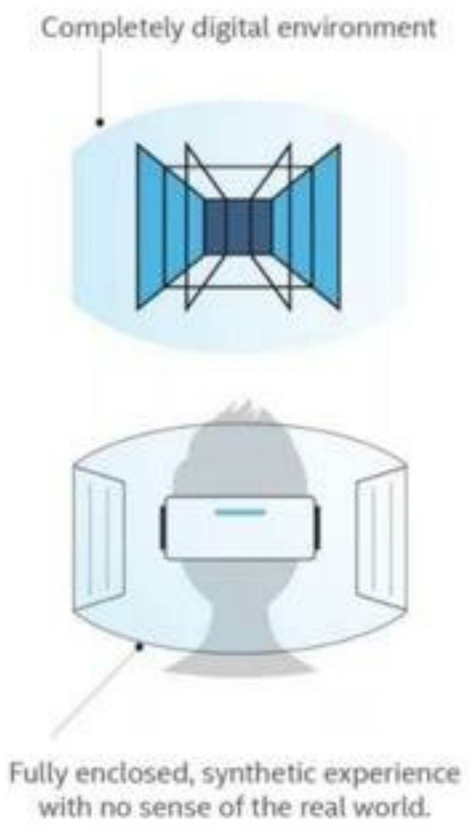
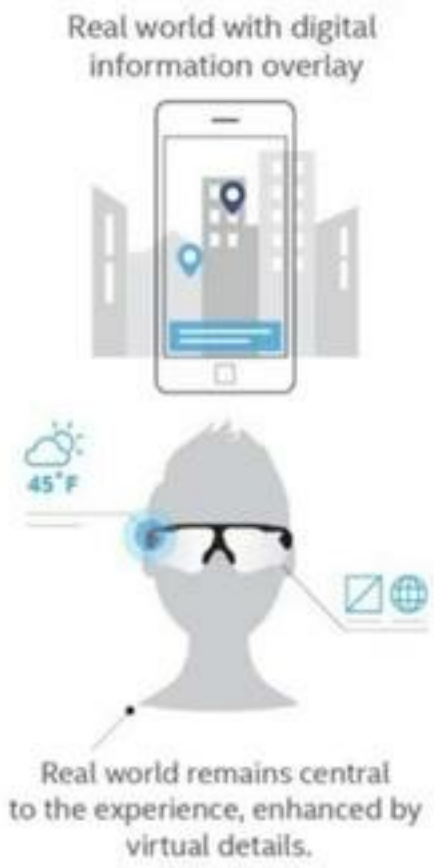


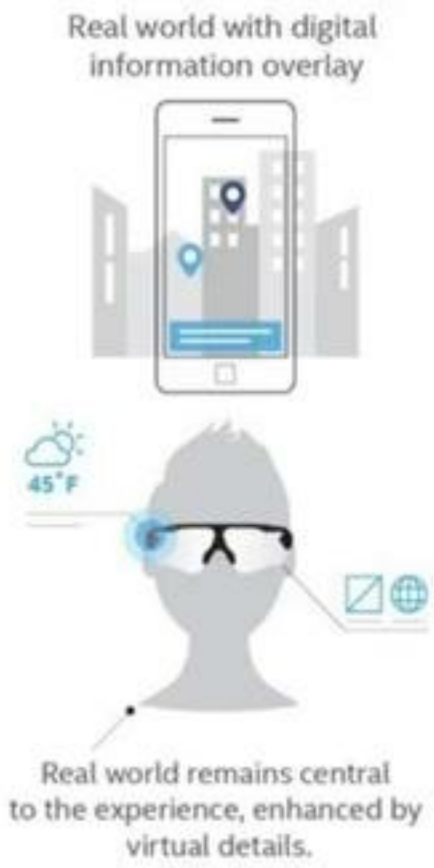
AR: Augmented Reality



AR: Augmented Reality

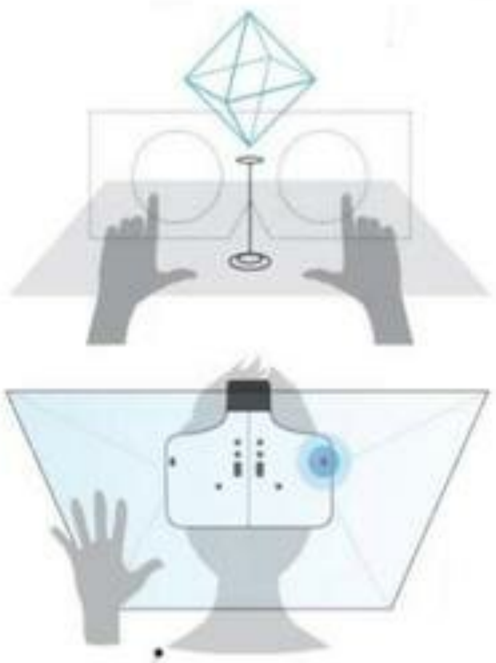
AR: Augmented Reality

AR: Augmented Reality



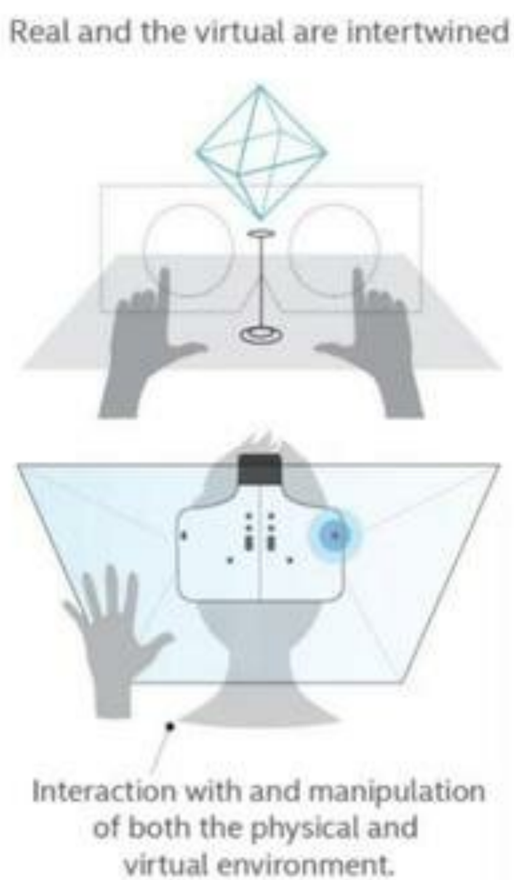
MR: Mixed Reality

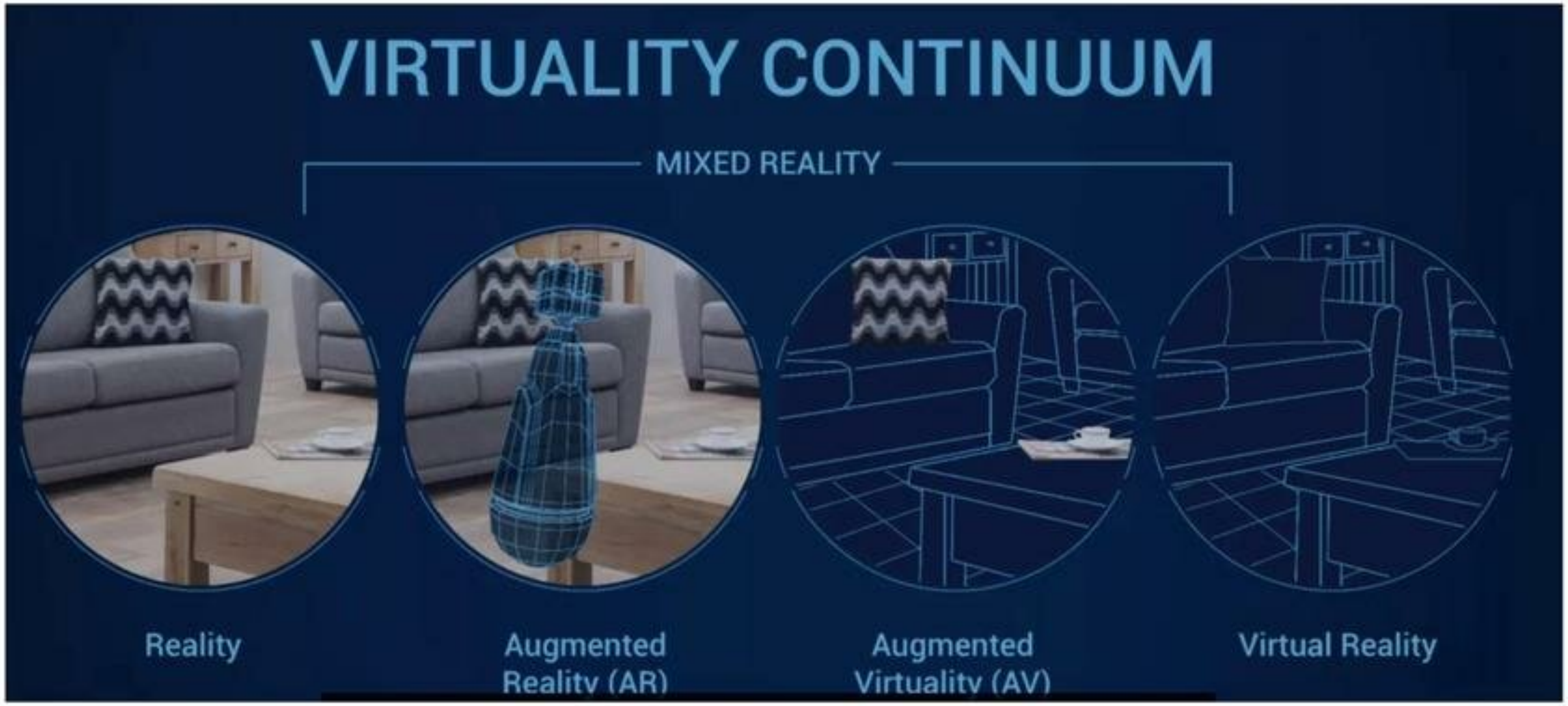
Real and the virtual are intertwined

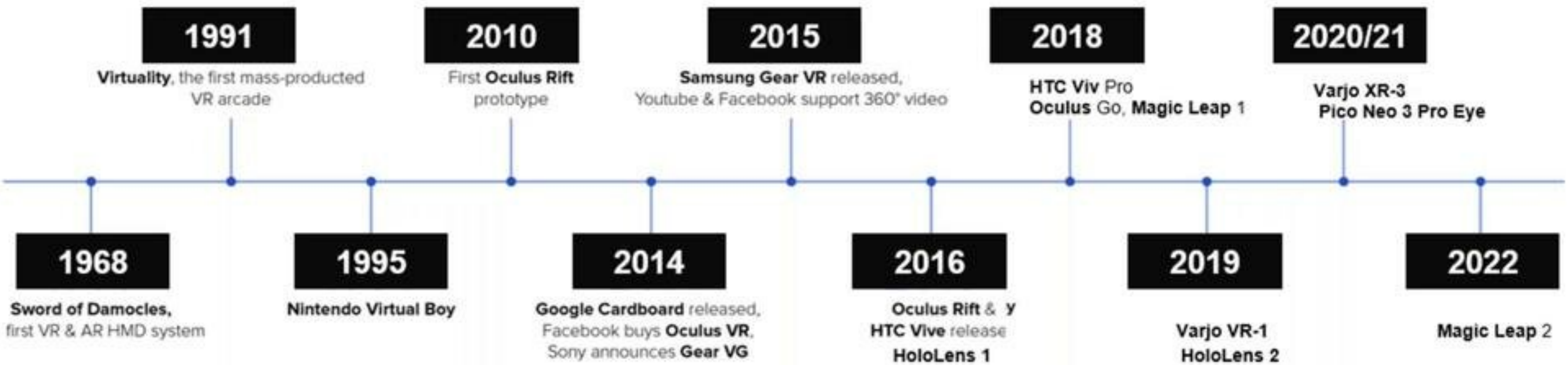


Interaction with and manipulation of both the physical and virtual environment.

MR: Mixed Reality

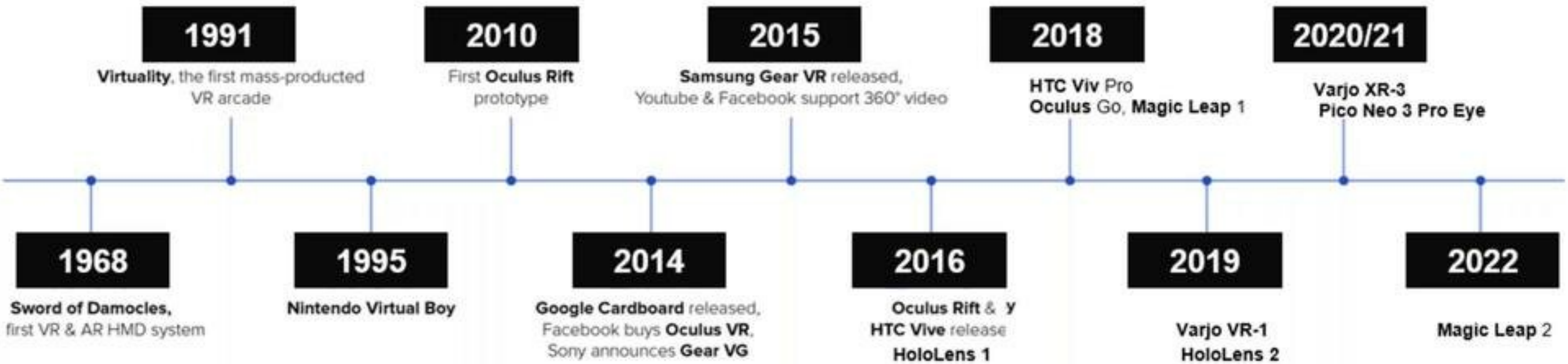



VIRTUALITY CONTINUUM
MIXED REALITY
Reality
Augmented Reality (AR)
Augmented Virtuality (AV)
Virtual Reality



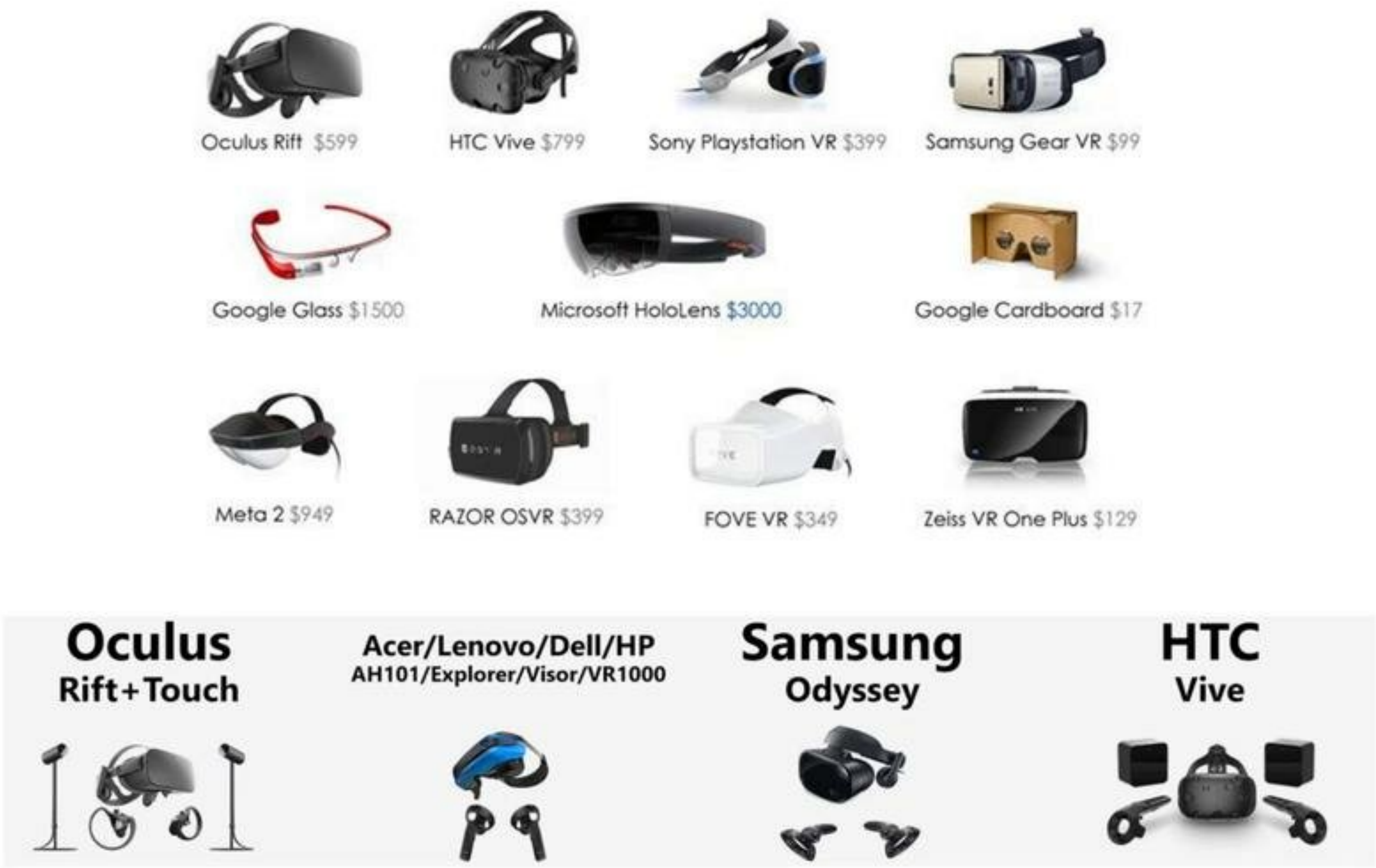
By Ivan Sutherland, 1960 for first time

By Ivan Sutherland, 1980 for first time



By Ivan Sutherland, 1960 for first time


Oculus Rift $599
HTC Vive $799
Sony Playstation VR $399
Samsung Gear VR $99
Google Glass $1500
Microsoft HoloLens $3000
Google Cardboard $17
Meta 2 $949
RAZOR OSVR $399
FOVE VR $349
Zeiss VR One Plus $129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FOVE VR $349
Zeiss VR One Plus $129
Oculus
Rift+Touch
Acer/Lenovo/Dell/HP
AH101/Explorer/Visor/VR1000
Samsung
Odyssey
HTC
Vive

VR Experience

Type of VR Experiences

360 Video

Cardboard

Mobile VR Headsets

Room-Scale VR

LEVEL OF IMMERSION
VISION
MONO
STEREO
REALITY LIKE
SOUND
MONO
STEREO
AMBISONIC
MOVEMENT
3 DOF
6DOF
INPUT
CONTROLER
VOICE
HANDS
BODY
FEEDBACK
TACTILE
KINESTHETIC

VR 360 Videos:

What is it?

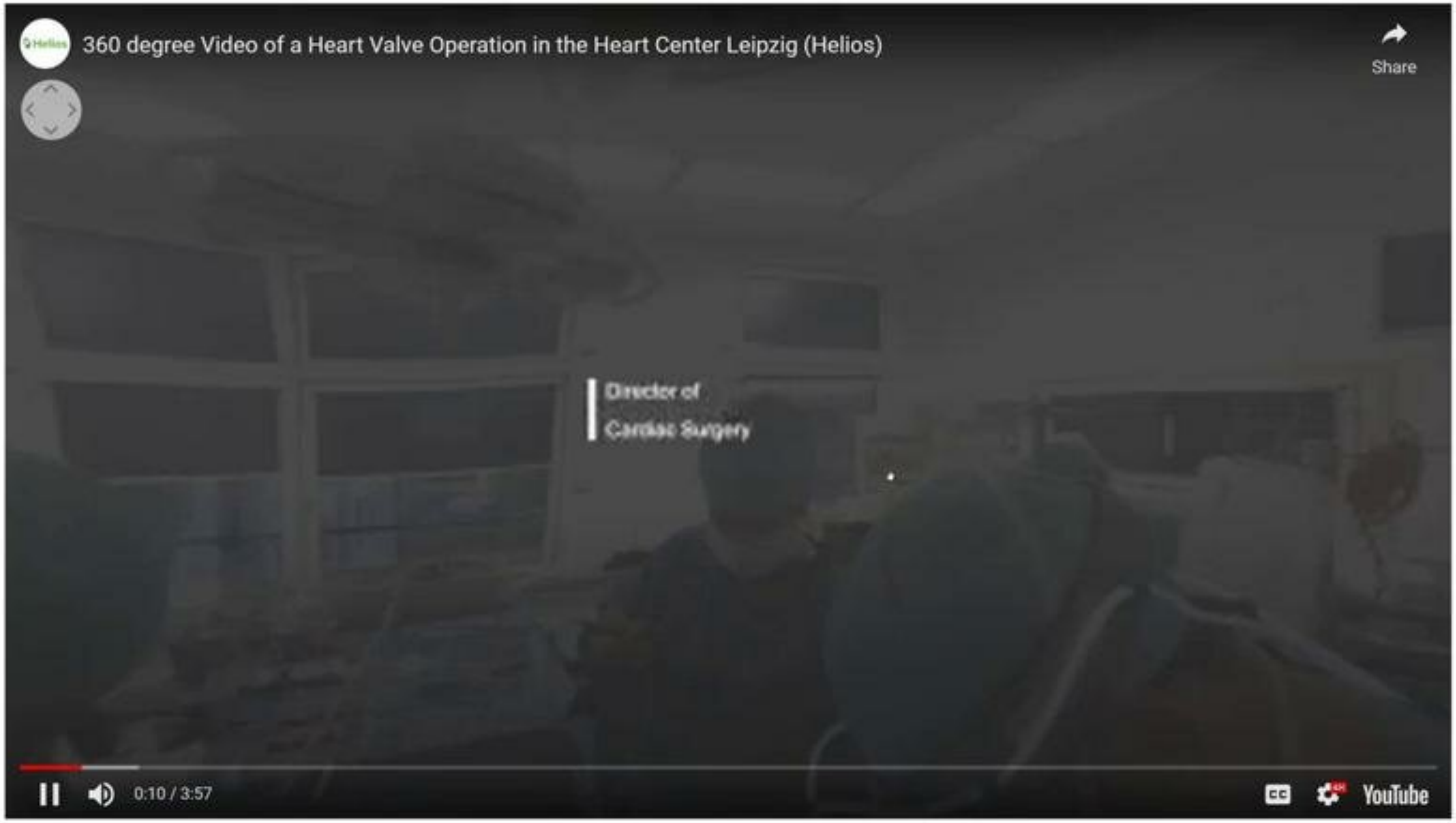
How to record?

How to Use?

What is it? Example in Manufacturing

What is it? Example in Manufacturing

What is it? Example in Surgery



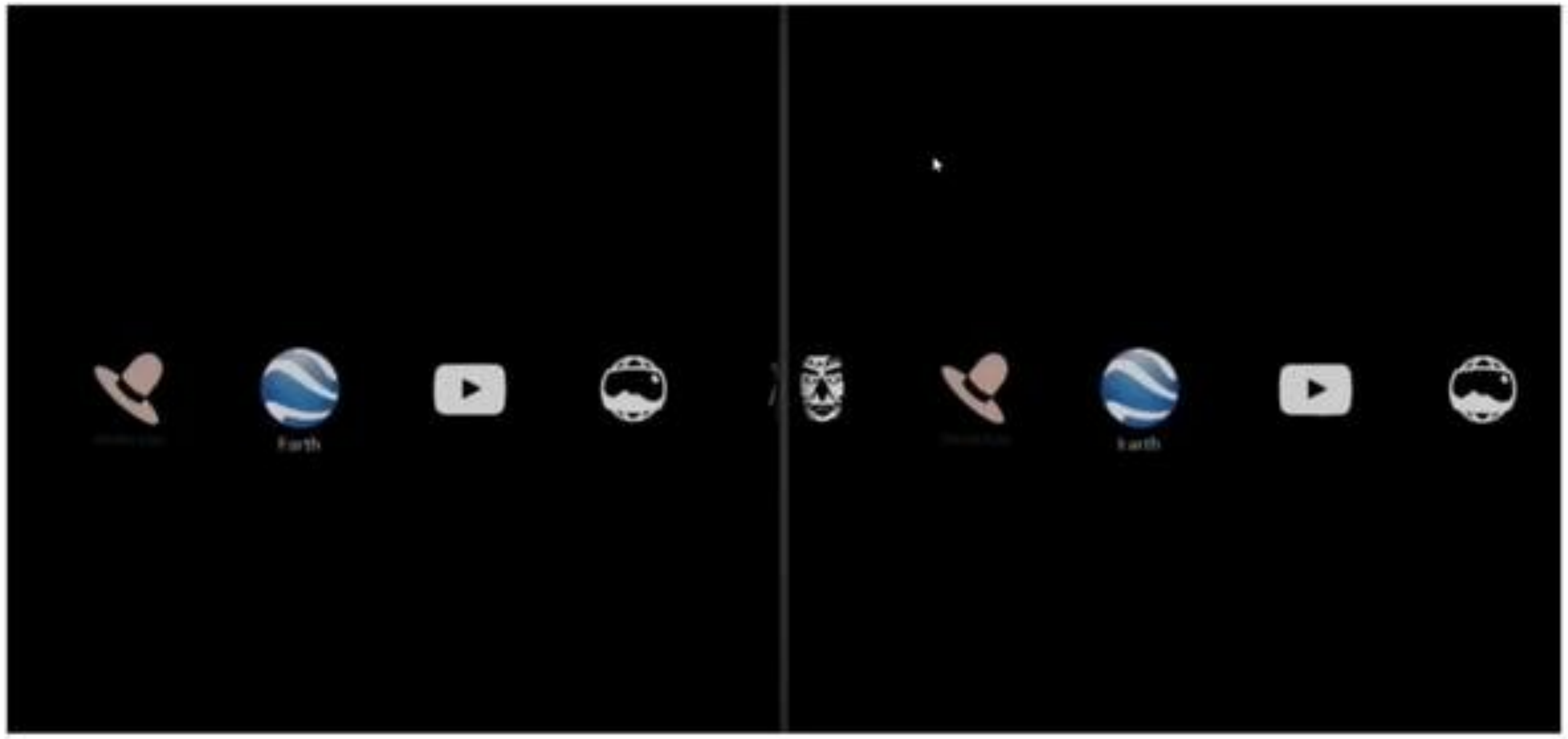
How to Record?

How to Record?

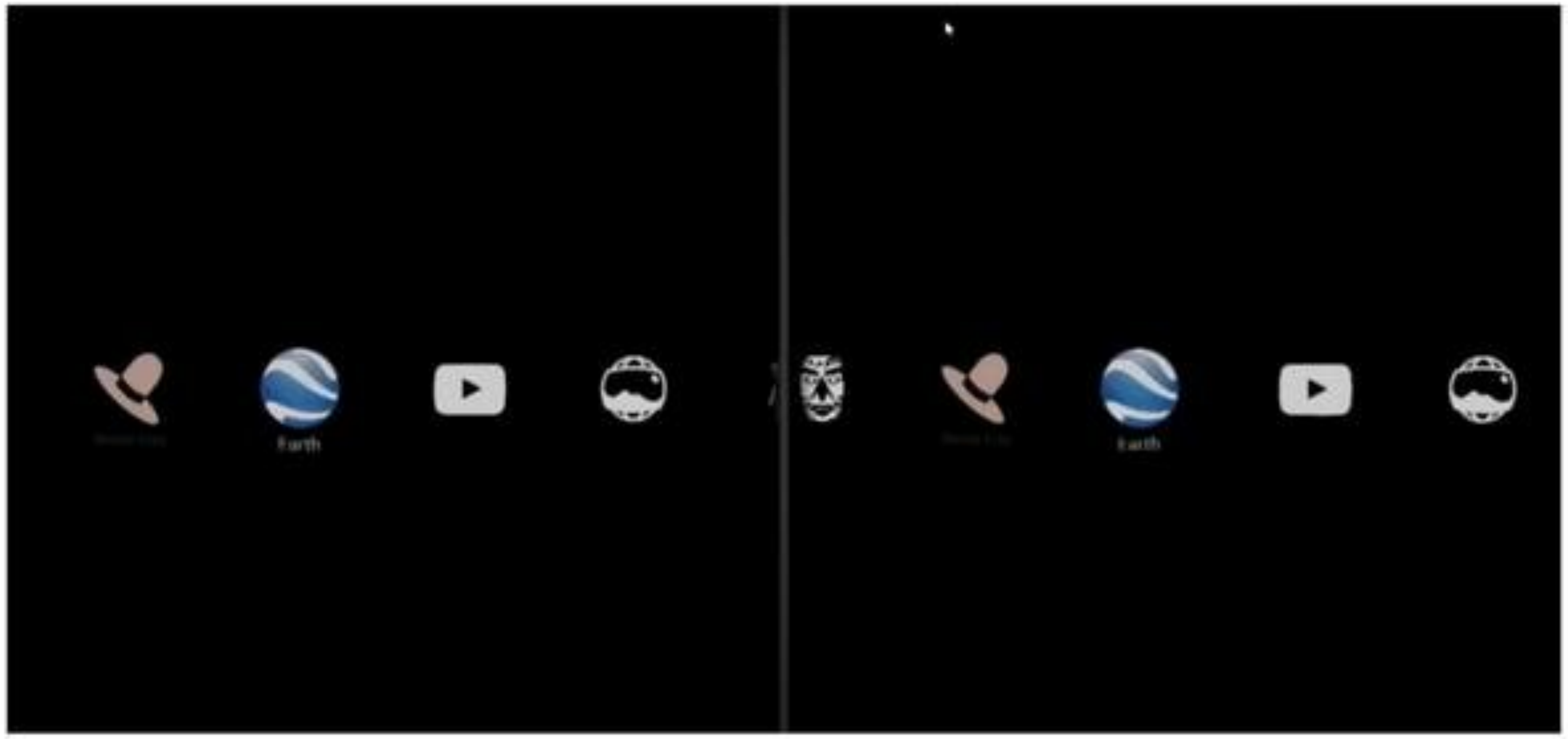
How to Use?

How to Use?

Cardboard



Cardboard



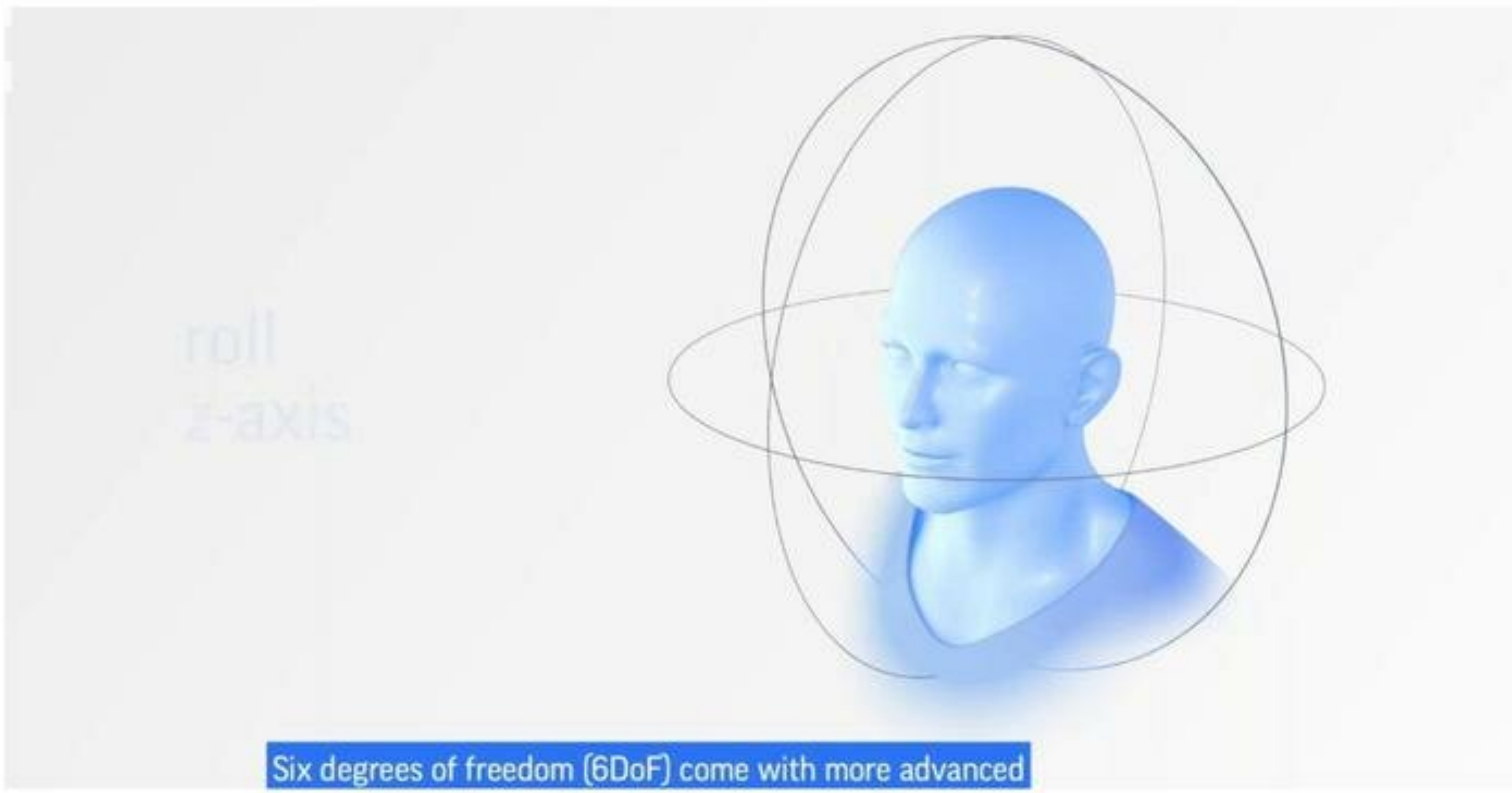
Cardboard

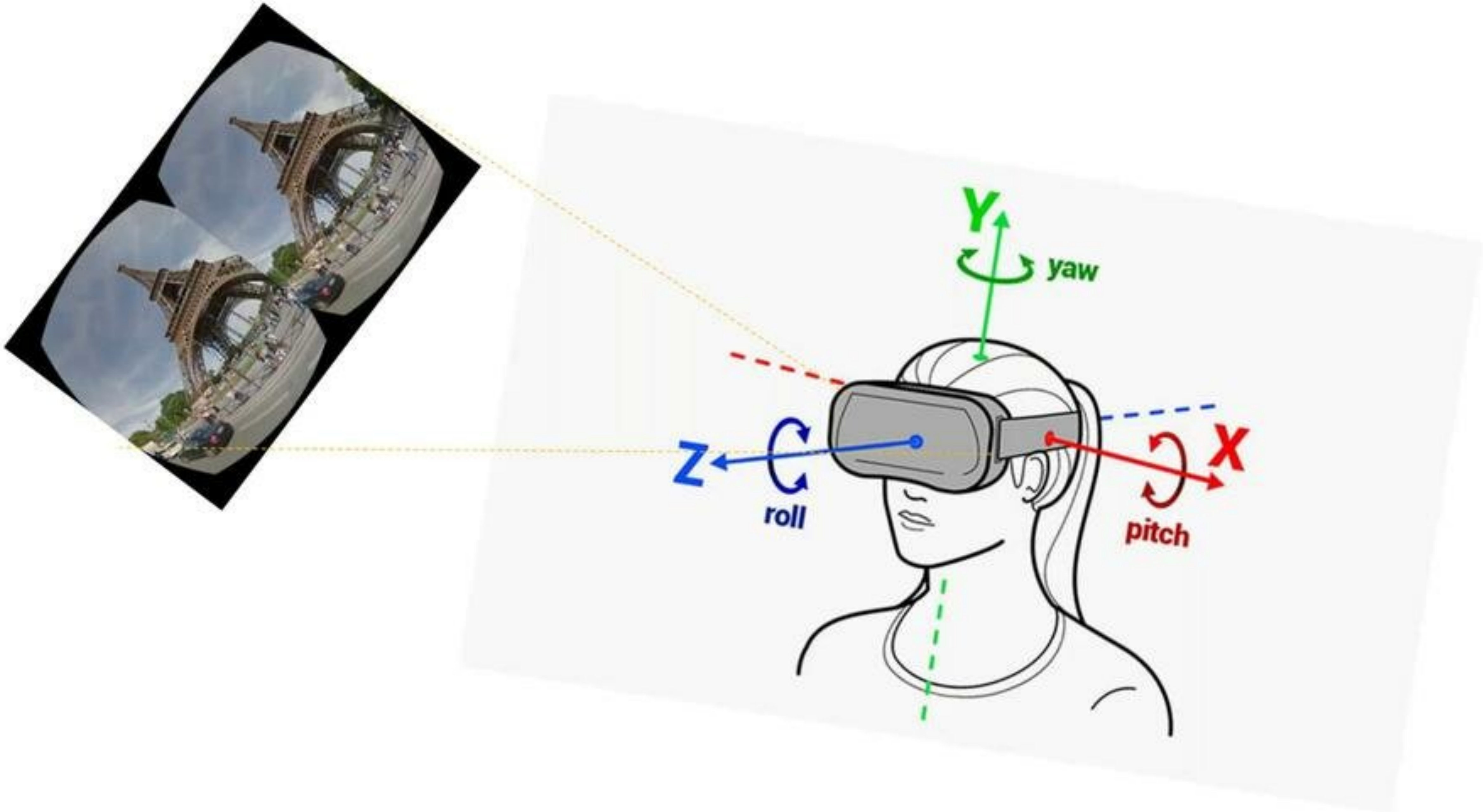
DoF (Degree of Freedom):

3DoF vs 6DoF

DoF (Degree of Freedom):

3DoF vs 6DoF





Y
yaw
Z
roll
X
pitch

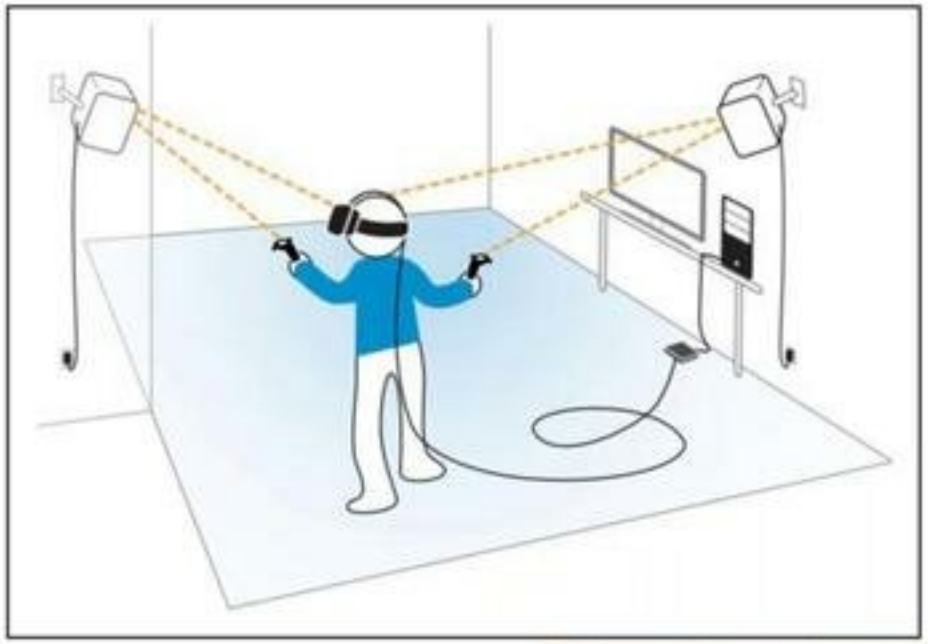
Mobile VR

Mobile VR

Mobile VR

Room Scale VR

VIVE - VR Headsets



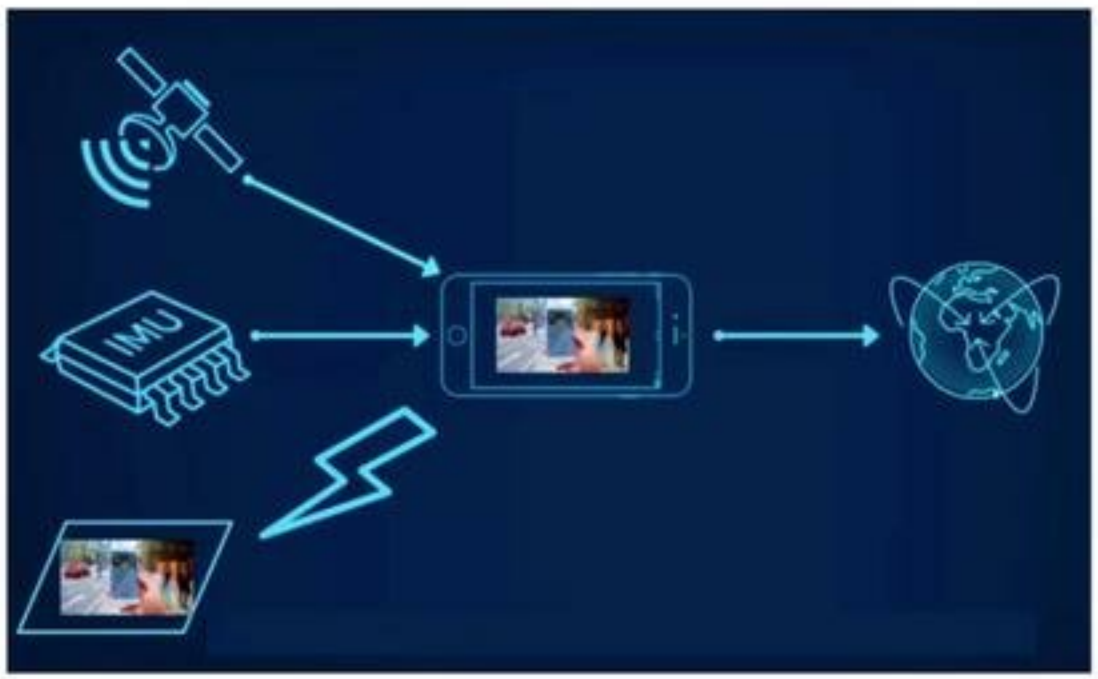
Oculus Quest 2

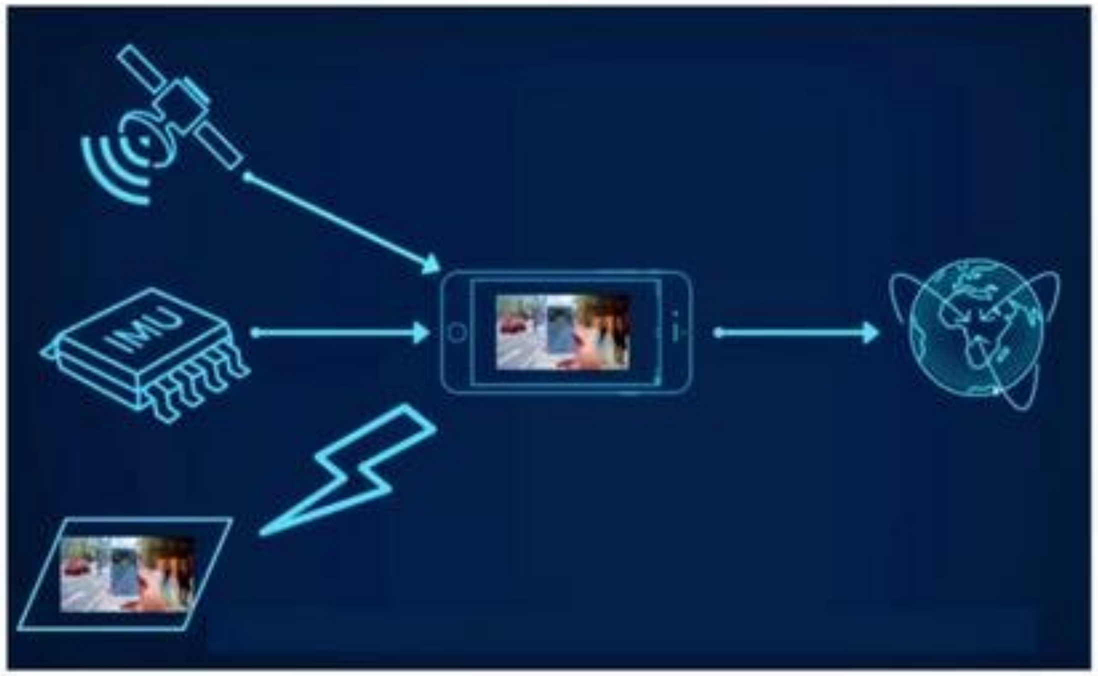
HTC Vive and Vive PRO

Windows 10 Mixed Reality Headsets

Oculus Rift and Oculus Touch

AR Experience


IMU


IMU


Snapshop Showroom

Different AR Experience

Marker-based AR	Marker-less AR	Head-worn AR
Using marker as portal into AR world	Using device as lens into AR world	Seeing the AR world directly and always

Marker-based AR

Marker-based AR

(a) Augmented Reality application running on a smart-phone

(b) Template Marker (c) Bar-code Marker (d) Circular Marker

Let's try marker-based AR

https://ar-code.com/

Basically Any Object Can Be a Marker

Codes

QR code or barcode scanner, e.g., can also encode a URL

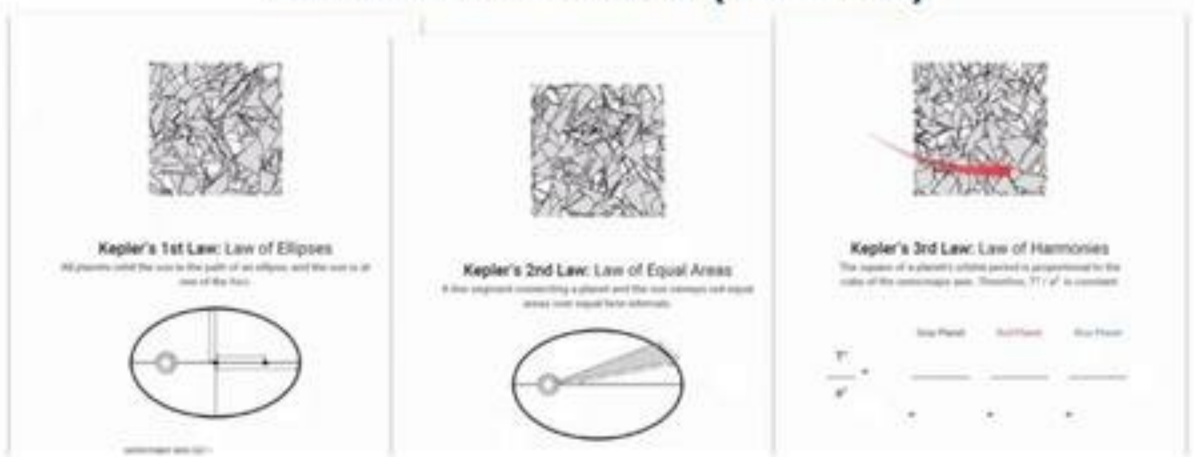
Faces, images and photos

Face and image recognition, e.g., business cards, brands, an

3D models

Object recognition of intricate 3D objects, e.g., action figures

Custom Markers (Vuforia)



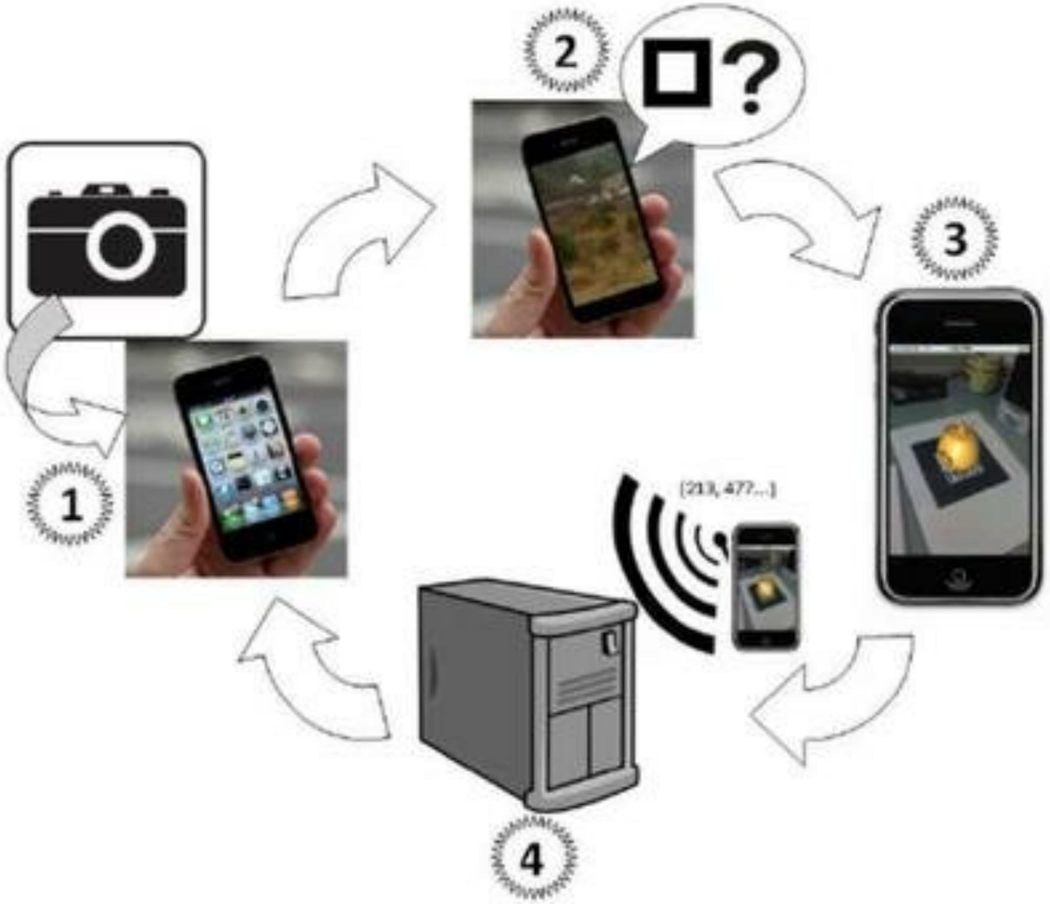
Marker-less AR

Marker-less AR

- Recognize objects rather than markers

Marker-less AR

- Recognize objects rather than markers



Marker-less AR Applications

High-end Devices

Scene Understanding

Believable Experiences


REDESIGN
Product Overview

ARvid Augmented Reality

AR Metaverse

Elie F. Gebran

#172 in Graphics & Design

Free · Offers In-App Purchases

ARvid Augmented Reality

AR Metaverse

Elie F. Gebran

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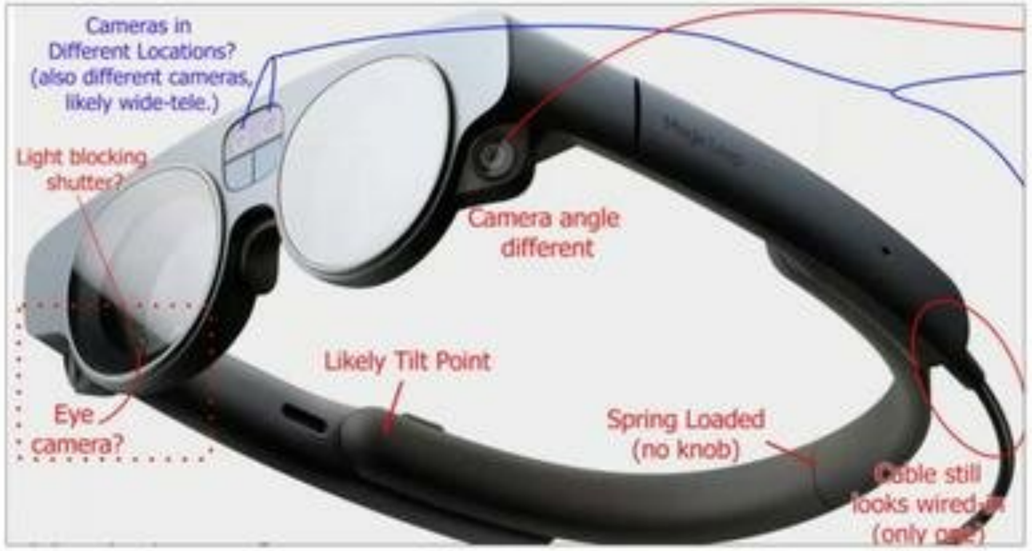
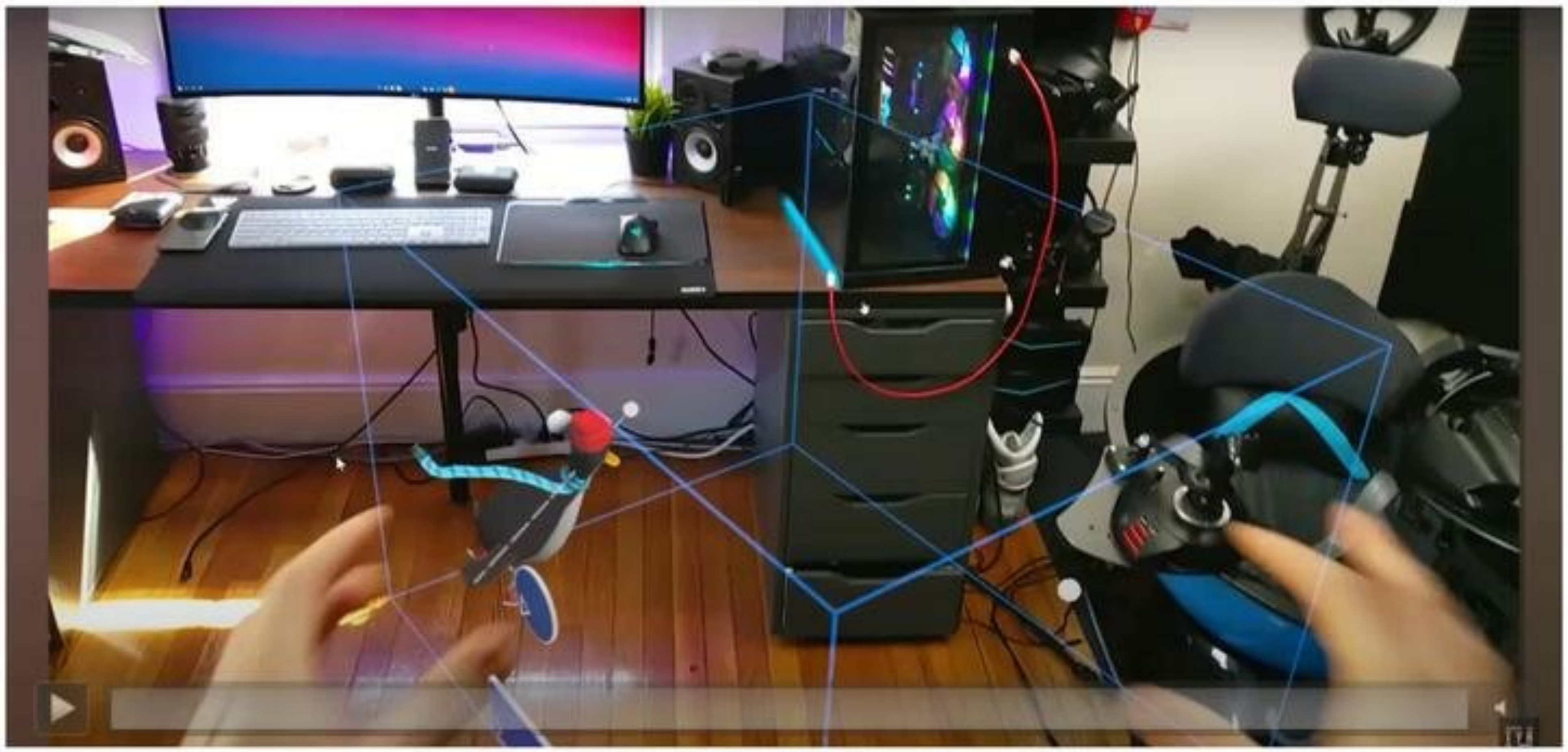
Head-worn AR

HoloLens 2

Magic Leap 2





HoloLens 2

Head-worn AR Applications

Very High-end Devices	Direct Manipulation	Multimodal Interaction

Marker-less Tracking

Think of a layered approach to marker-less tracking:

- **Plane detection**

  Horizontal & vertical planes

- **Spatial mapping**

  3D mesh reconstruction & texture mapping

- **Scene understanding**

  Classification: face, walls, floors, tables, seats, windows, ceilings, …

  Segmentation: foreground/background, sky, people, ...

Hand-held vs. Head-worn AR

Hand-held vs. Head-worn AR

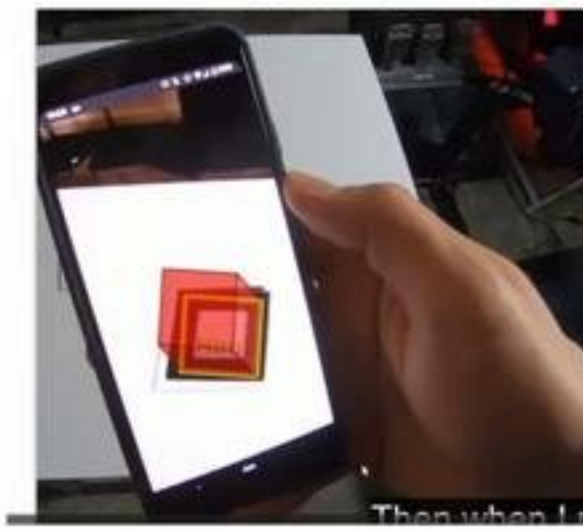
Varying display sizes	Usually small display (FOV)

Hand-held vs. Head-worn AR

Varying display sizes	**Usually small display (FOV)**
Mix of 2D/3D content + touch • 2D screen + touch • 3D world + touch • Device motion gestures • Voice commands	**HUD + 3D content + gesture** • HUD + hand/voice • 3D world + hand gestures • Head/eye gaze • Voice commands
Marker-based *or* marker-less • Marker-based tracking • Marker-less tracking	***Advanced* tracking with** • Inside-out 6DOF tracking • Spatial mapping

Marker-based Tracking (AR.js)

Marker Tracking (ARToolKit)



1) **Original image**
   Extract frame by frame
2) **Threshold image**
   Segment out the marker
3) **Connected components**
   Identify marker components
4) **Contours**
   Get rough shape
5) **Marker edges & corners**
   Extract marker
6) **Fitted square**
   Estimate marker pose

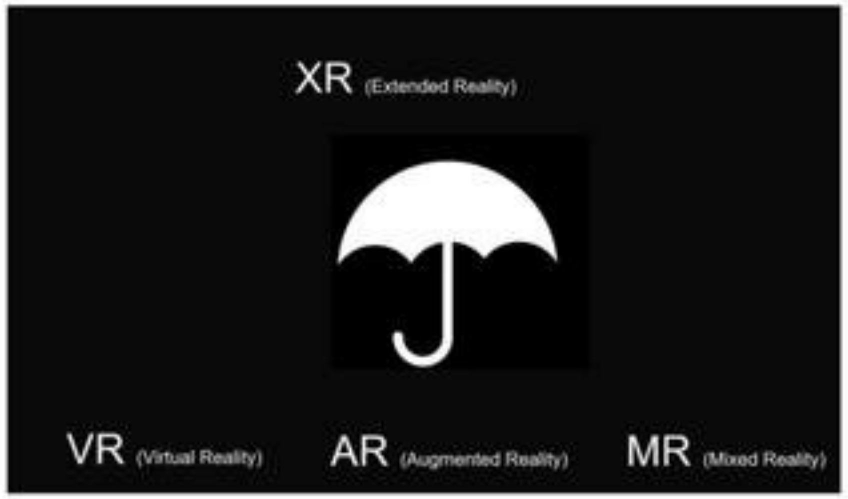
Then when I put all the pieces

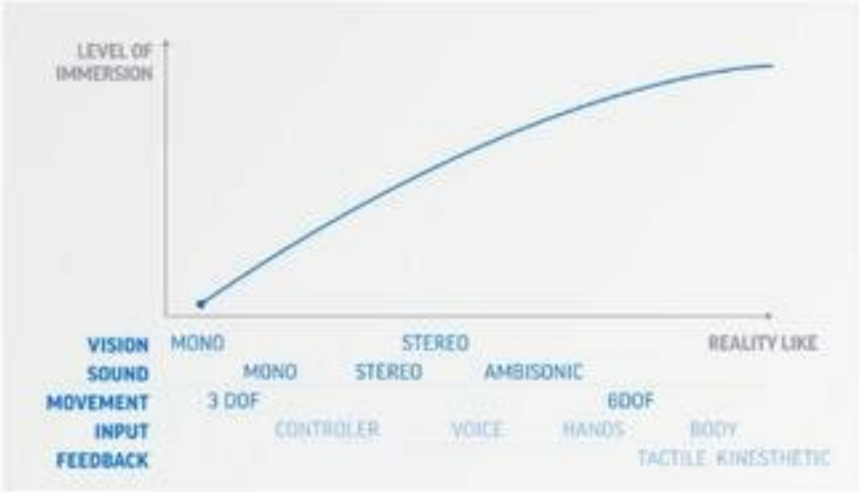
Plane Detection (WebXR)

Depth API (ARCore)

Recap!

Recap!


XR (Extended Reality)
VR (Virtual Reality)
AR (Augmented Reality)
MR (Mixed Reality)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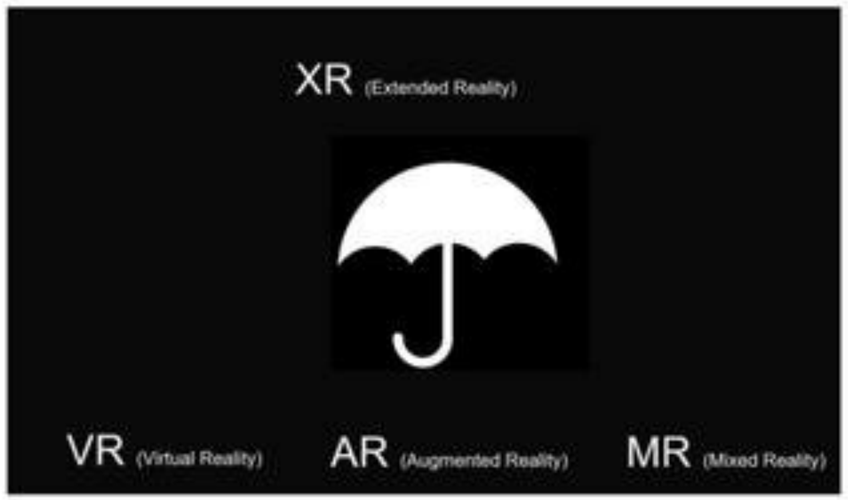
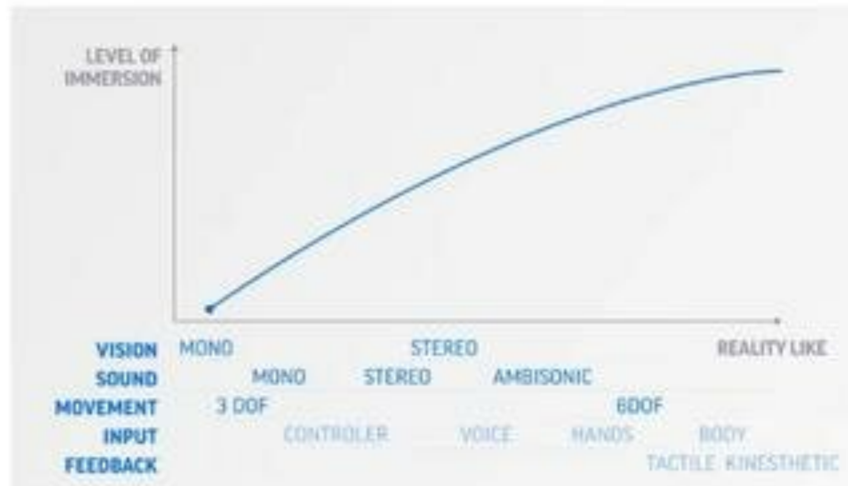
Recap!





360 Video

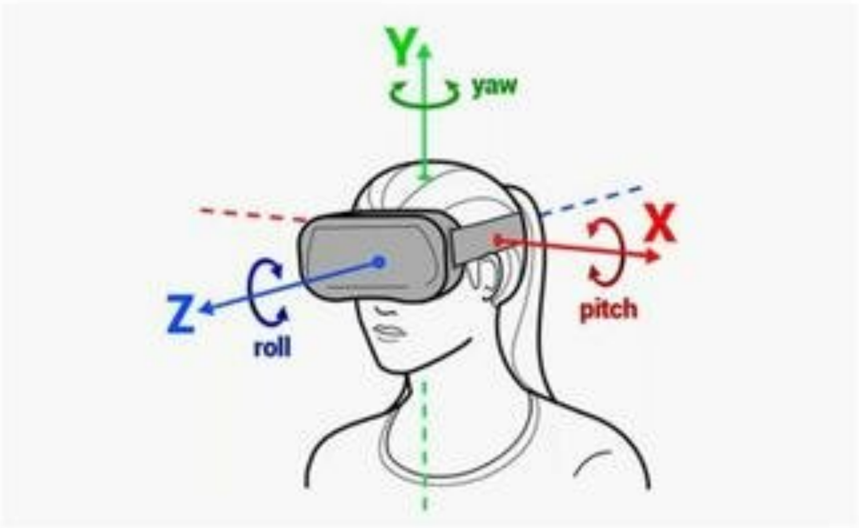
Cardboard

Mobile VR Headsets

Room-Scale VR

Recap!

Cardboard



Mobile VR

Room Scale VR

VIVE - VR Headsets

Oculus Quest 2

Recap!

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Recap!

Different AR Experience

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Using marker as portal into AR world

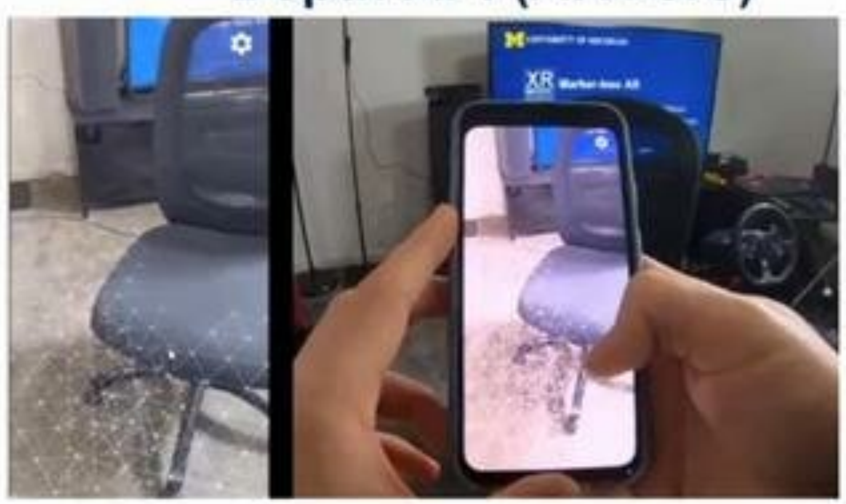
Marker-less AR

Using device as lens into AR world

Head-worn AR

Seeing the AR world directly and always

Depth API (ARCore)

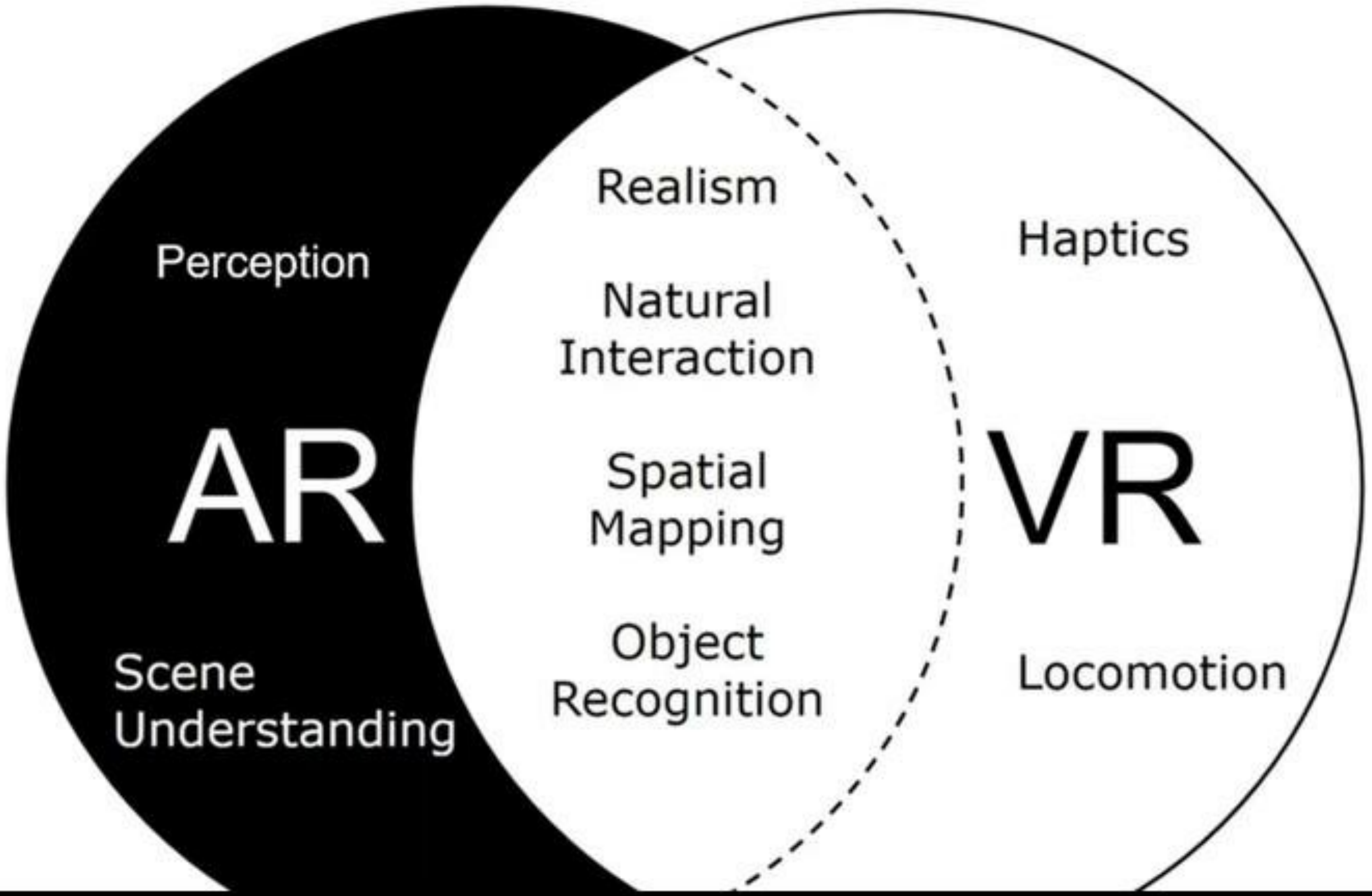


Other Topics in XR Design Process?

Well, there is too much!

What Matter in XR?

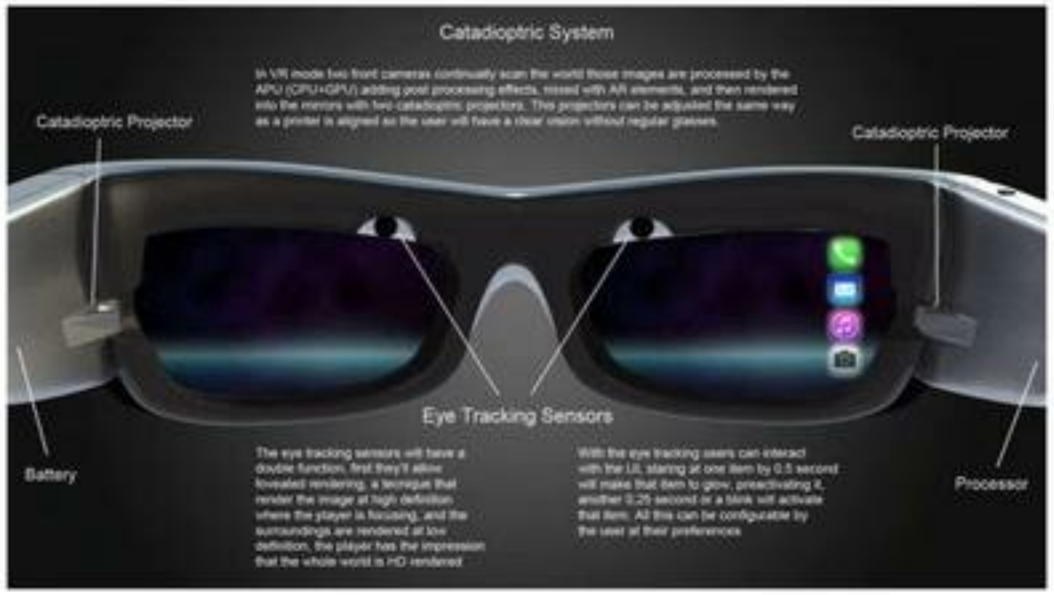
What Matter in XR?



Trend in XR Technology


Competitor device
Varjo VR-3 & XR-3

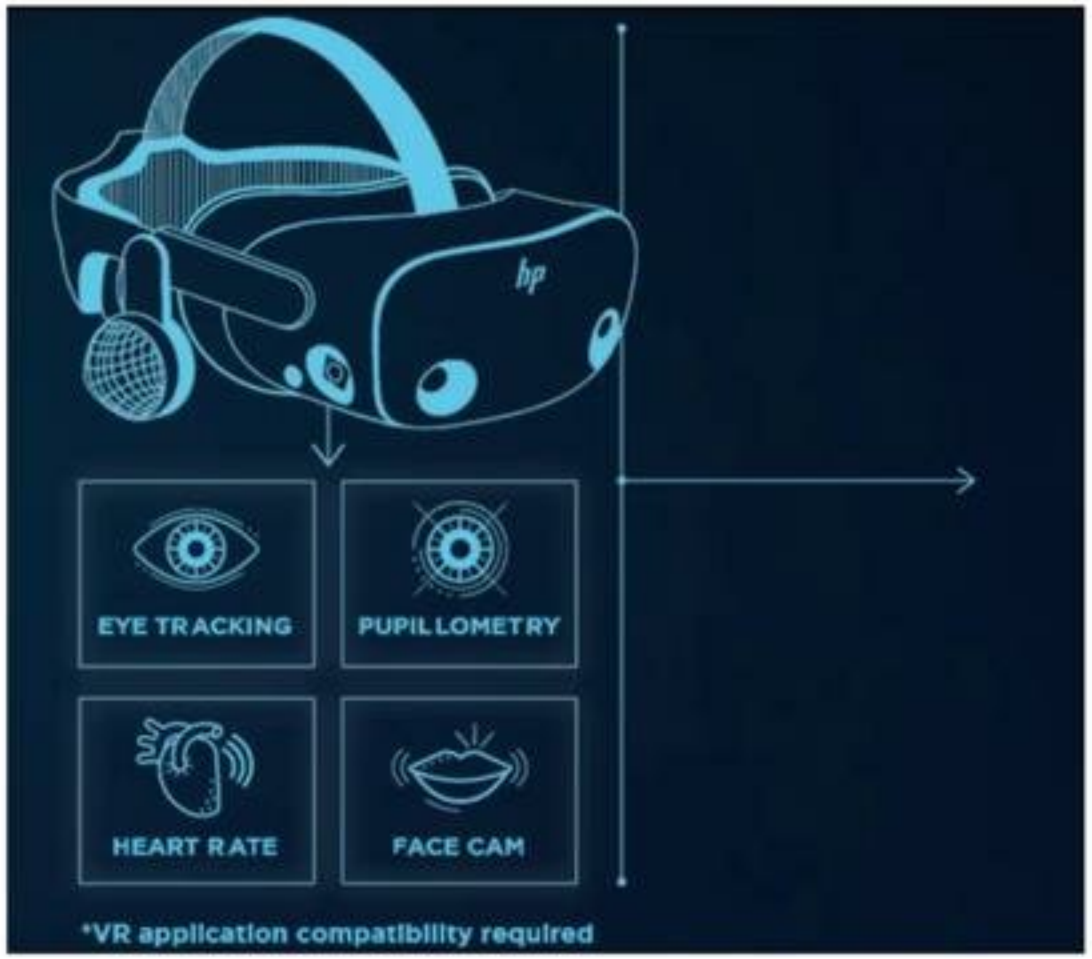

Leap Motion
Kinect
RealSense


Catadioptric System
Catadioptric Projector
Catadioptric Projector
Eye Tracking Sensors
Battery
Processor

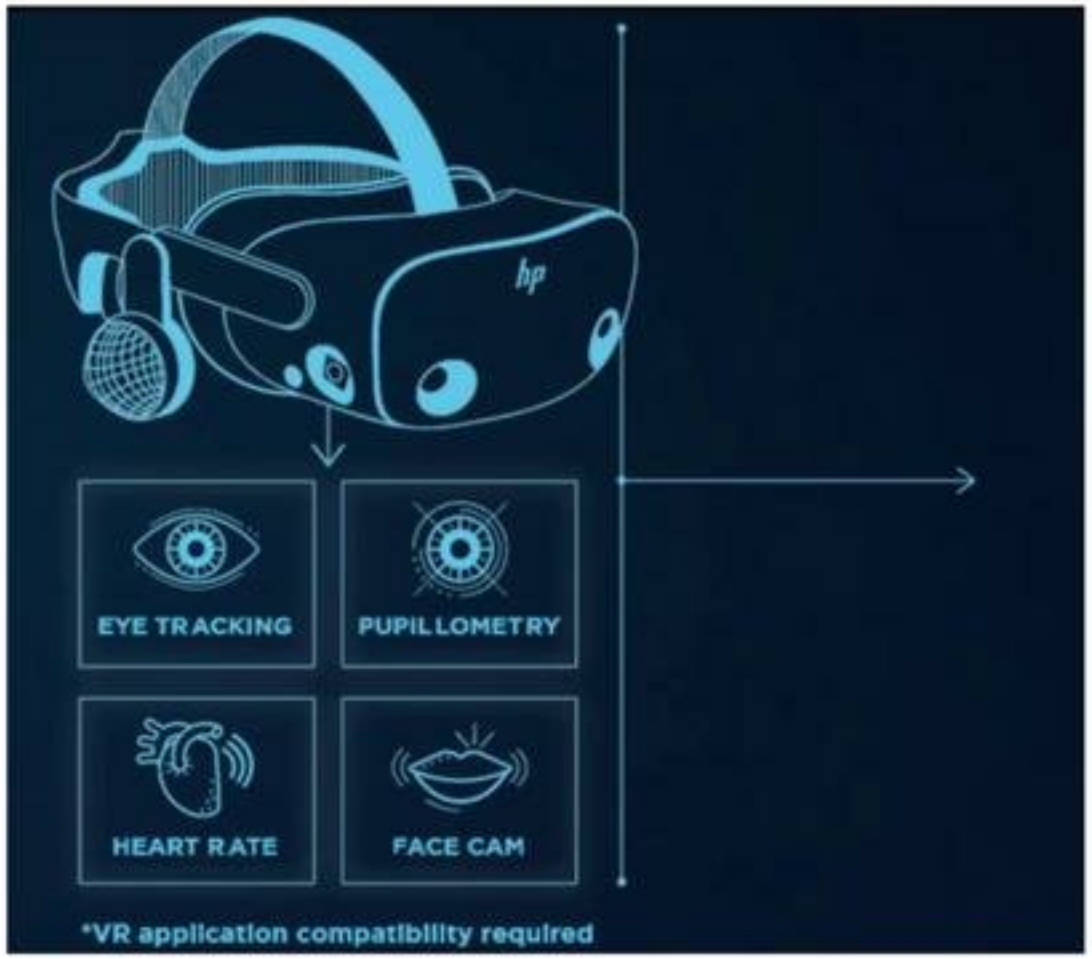

THE HP OMNICEPT SDK

Haptic Feedback

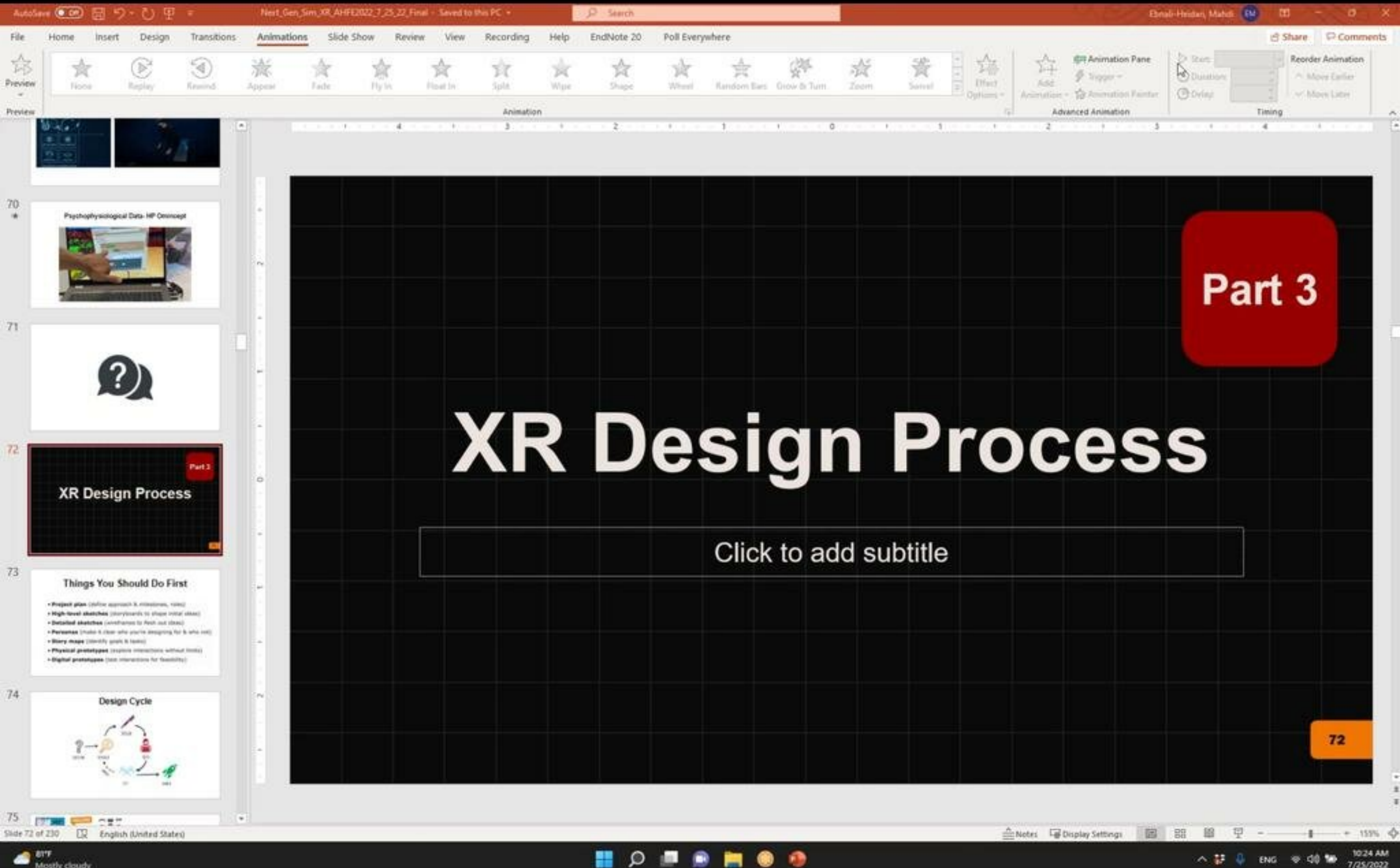
HP Omincept VR Headset



HP Omincept VR Headset



Psychophysiological Data- HP Omincept



Part 3
XR Design Process
Click to add subtitle
72
Things You Should Do First
Design Cycle
Psychophysiological Data- HP Omnicept

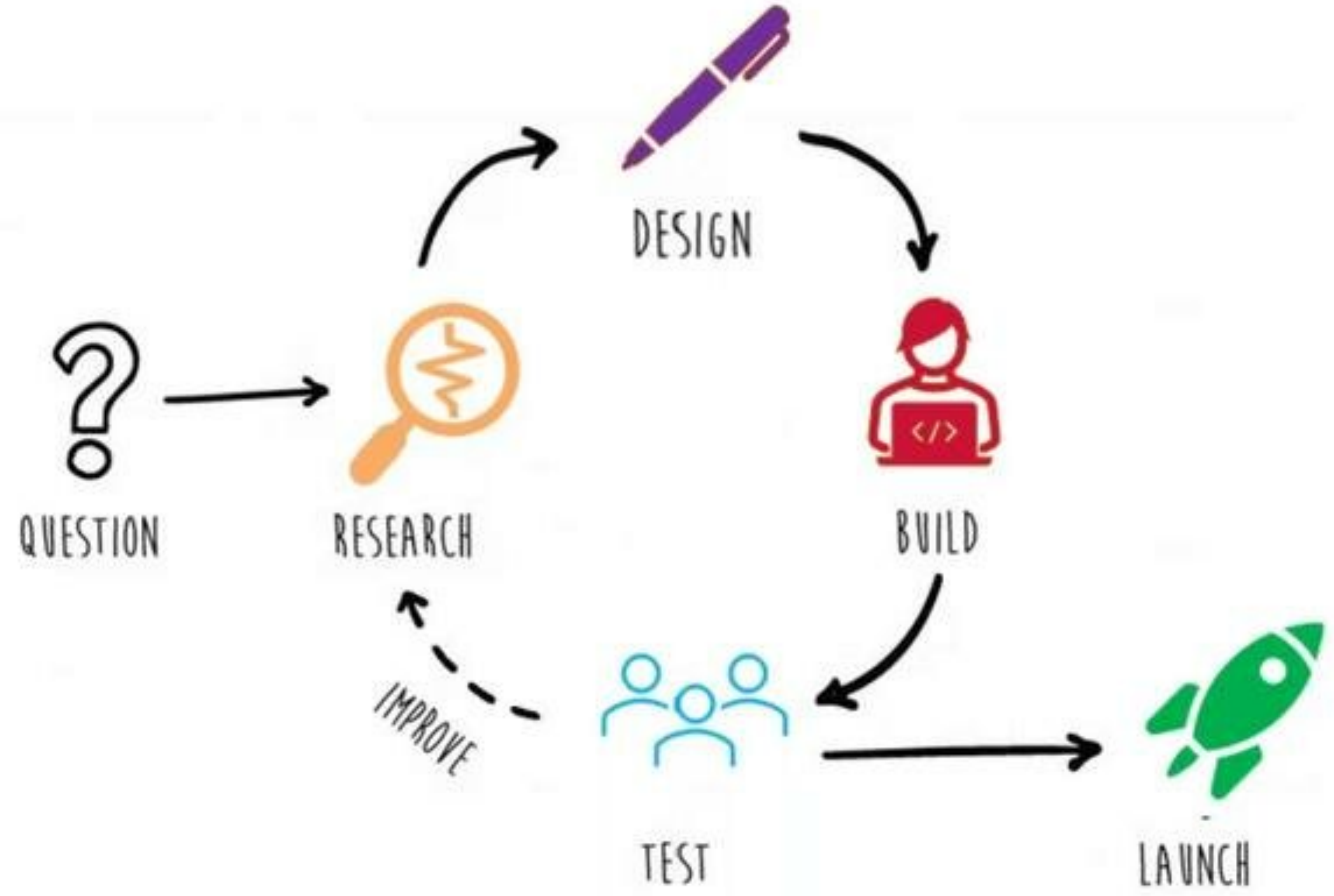
Part 3

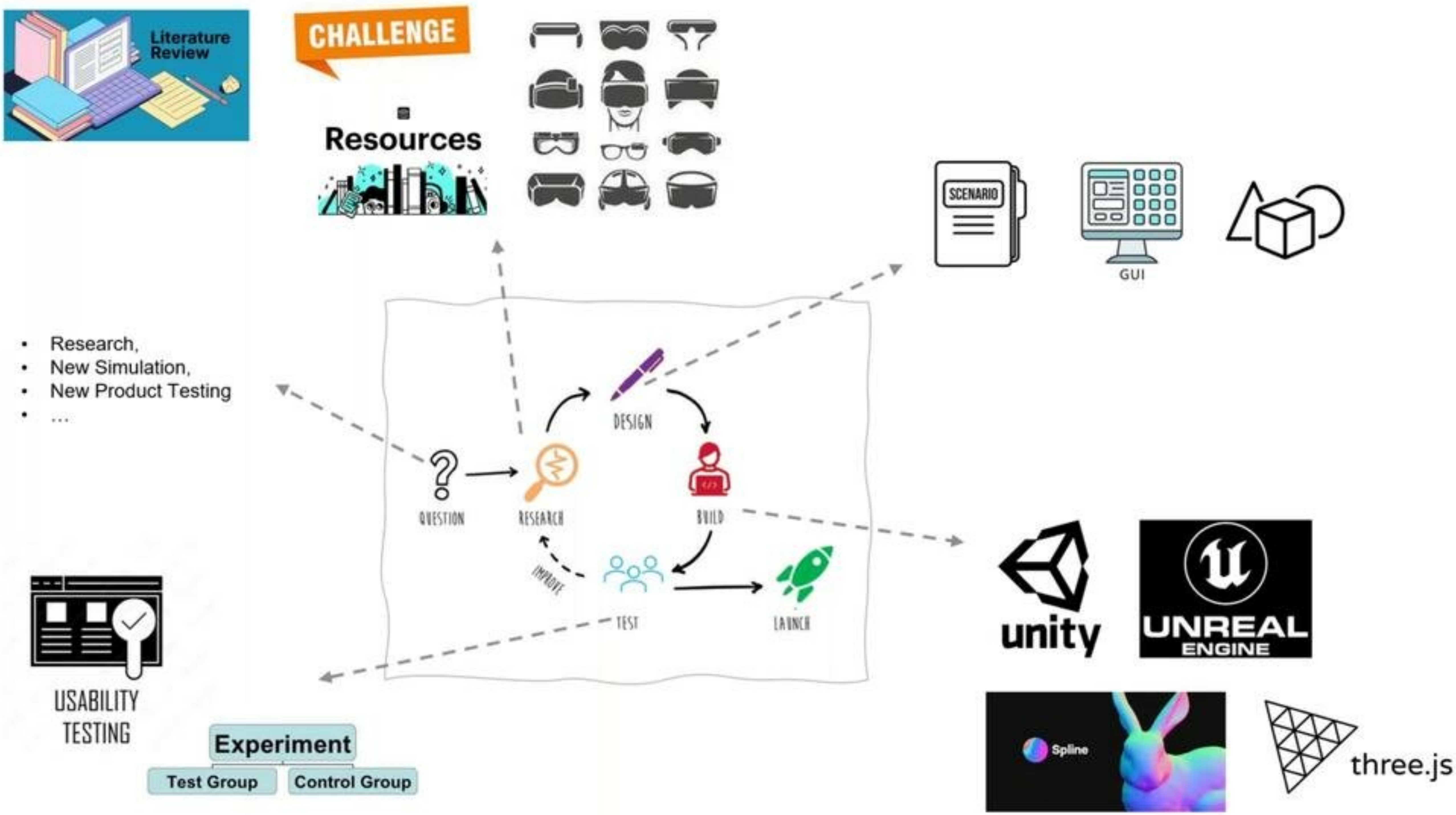
XR Design Process

Things You Should Do First

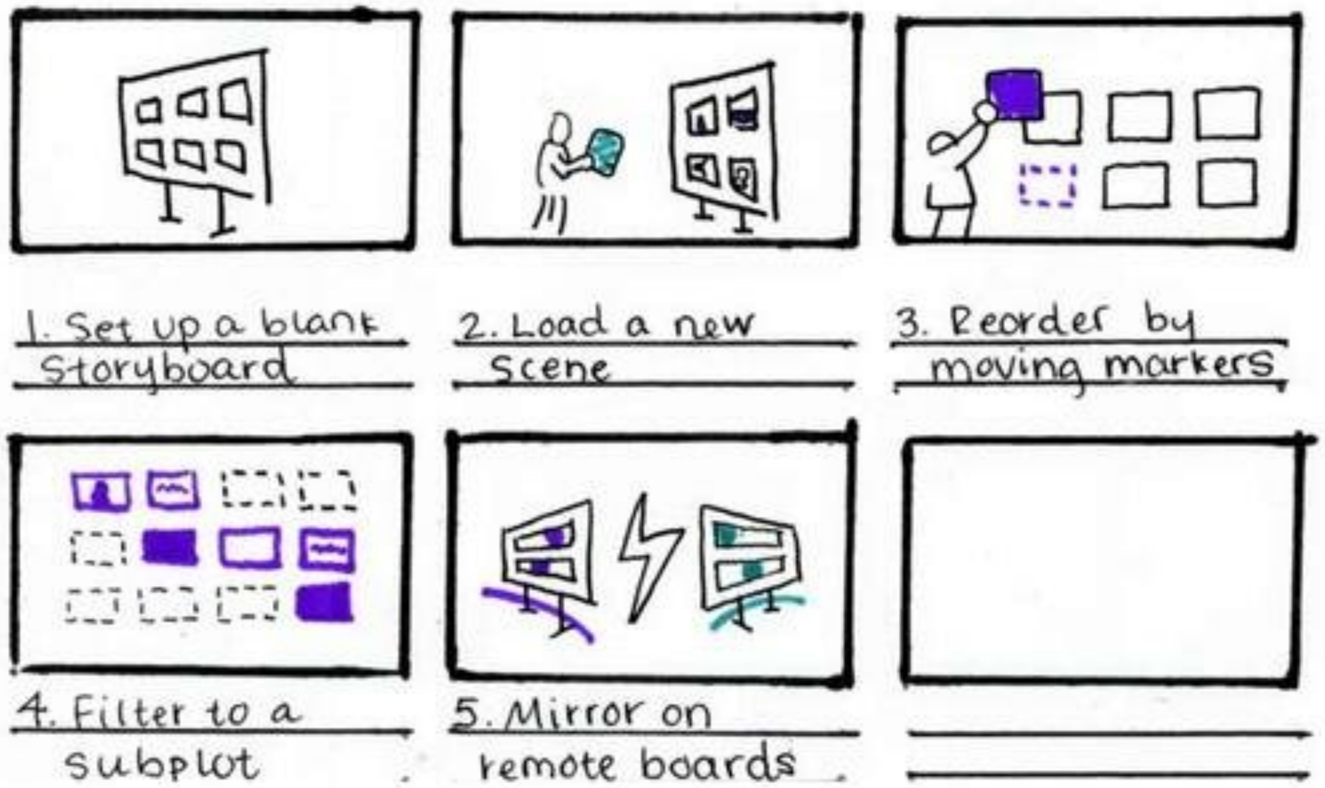
- **Project plan** (define approach & milestones, roles)
- **High-level sketches** (storyboards to shape initial ideas)
- **Detailed sketches** (wireframes to flesh out ideas)
- **Personas** (make it clear who you're designing for & who not)
- **Story maps** (identify goals & tasks)
- **Physical prototypes** (explore interactions without limits)
- **Digital prototypes** (test interactions for feasibility)

Design Cycle




Literature Review
CHALLENGE
Resources
SCENARIO
GUI
Research,
New Simulation,
New Product Testing
…
DESIGN
QUESTION
RESEARCH
BUILD
IMPROVE
TEST
LAUNCH
unity
UNREAL ENGINE
USABILITY TESTING
Experiment
Test Group
Control Group
Spline
three.js

Story Map / Paper-based Prototyping



Prototyping/ UX Design Tools

JUSTINMIND

miro

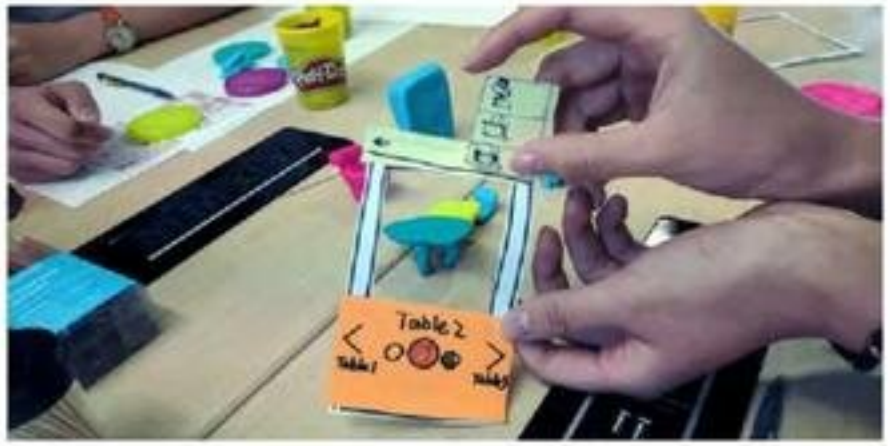
Figma

Physical Prototyping

http://michael-nebeling.de/publications/chi19course.pd
https://www.semanticscholar.org/paper/ProtoAR%3A-Rapid-Physical-Digital-Prototyping-of-Nebeling-Nebeling/ffadf852409700a4fcec4f8a96b28cbedee4beac/figure/0f

Physical Prototyping

- Quick & dirty
- Explore interactions
- Get initial user feedback
- Avoid premature commitment
- Devise technical requirements



(c) He creates a 360° capture of Play-Doh object

(d) He views 360° captured object in AR from similar angle

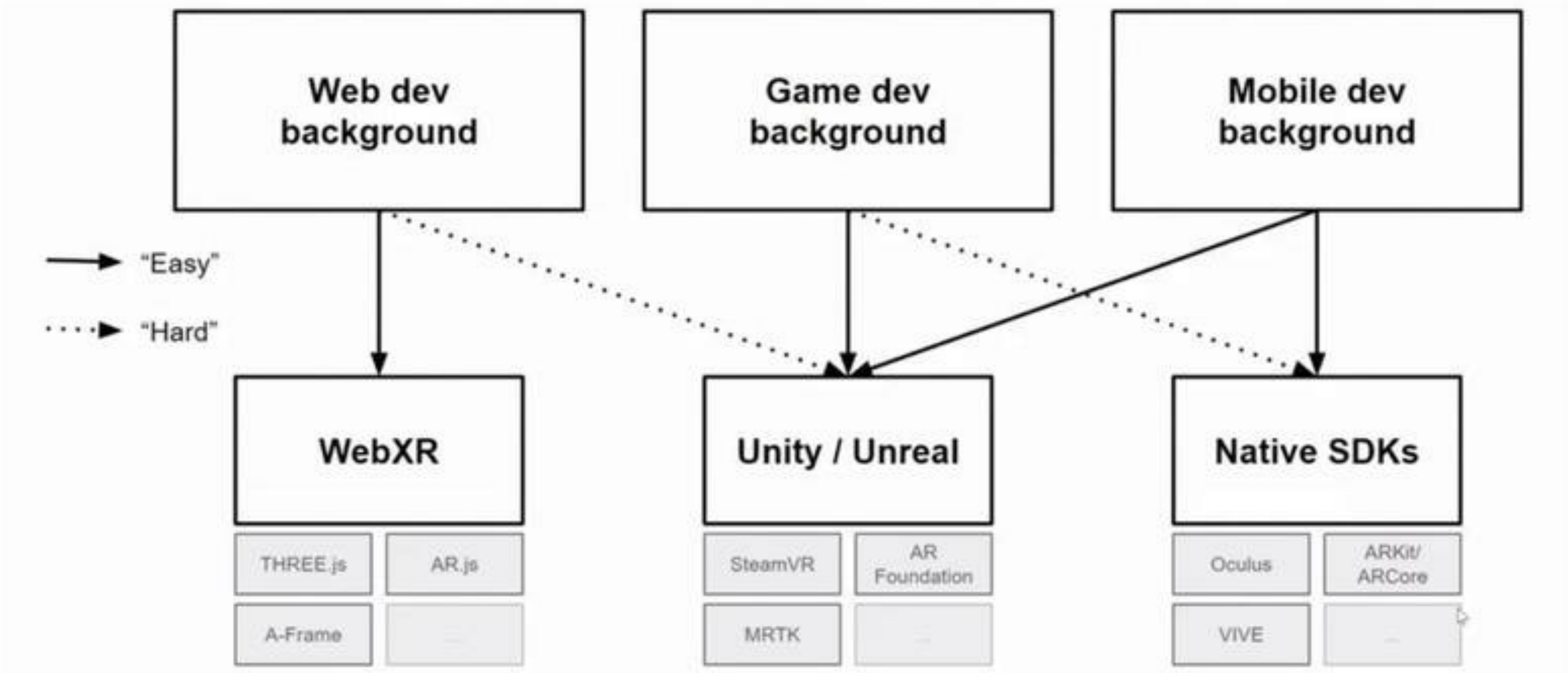
http://michael-nebeling.de/publications/chi19course.pd
https://www.semanticscholar.org/paper/ProtoAR%3A-Rapid-Physical-Digital-Prototyping-of-Nebeling-Nebeling/ffadf852409700a4fcec4f8a96b28cbedee4beac/figure/0f

Development

Development

WebXR	Unity / Unreal	Native SDKs
THREE.js	SteamVR	Oculus
AR.js	AR Foundation	ARKit/ ARCore
A-Frame	MRTK	VIVE
...	...	...

Pathway to be XR Creator



XR Toolkits

A-Frame
AR.js
SteamVR
MRTK
Vuforia
AR Foundation
XR Interaction

WebXR | unity | UNREAL ENGINE

Card-board | Oculus | VIVE | WMR

Web Cam | AR Core | AR Kit | Holo Lens

Unity vs. Unreal

Unity vs. Unreal

1. What level of visuals are you after?

Unreal offers high-quality visuals straight out of the box. Unity won't produce quite the same quality.

2. Are you a developer or a designer?

Developers often prefer Unity; designers/3D artists opt for Unreal.

3. What is your development environment?

Unity enables you to create complex projects for low-end devices. Unreal requires a powerful PC and broadband internet setup.

4. What device is your project aimed at?

XR Design Elements

What are? How to get / create?

XR Design Elements

What are? How to get / create?

XR Design Elements

What are? How to get / create?

Design Elements

What are? How to get / create?

Scenarios / Stories

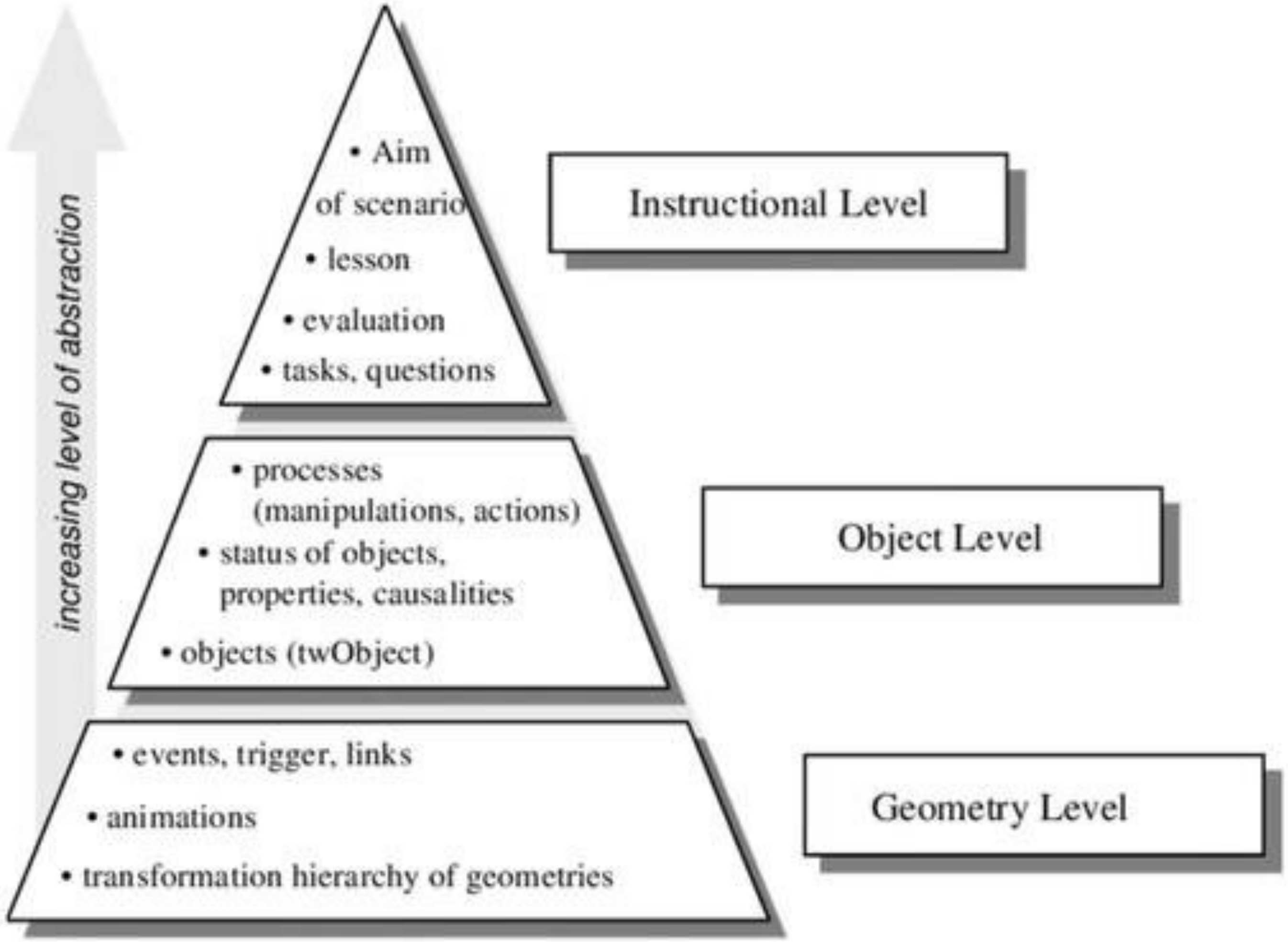
Non-human 3D Objects

Human 3D Objects

UIs

Scenarios / Stories

Scenarios / Stories



Needfinding & Brainstorming

Framing the problem via scenarios & use cases, personas, and competitors

Storyboarding & Prototyping

Creating mockups using paper and digital tools, involving XR devices

Non-Human 3D Objects

Places to find 3D models

Programs to create 3D models

Non-Human 3D Objects

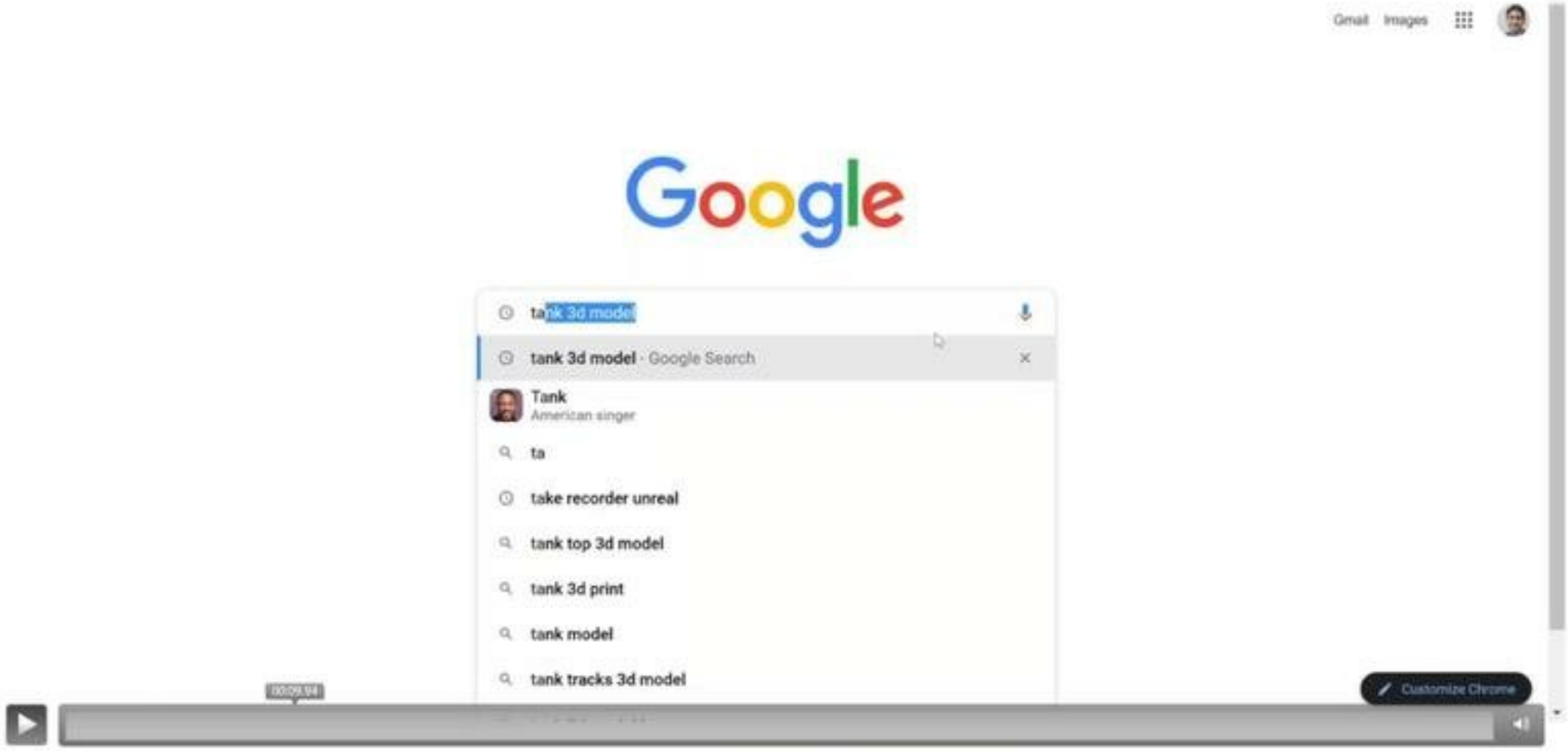
Places to find 3D models

- Sketchfab
- Google Poly
- SketchUp's 3D Warehouse
- Clara.io
- Adobe Mixamo

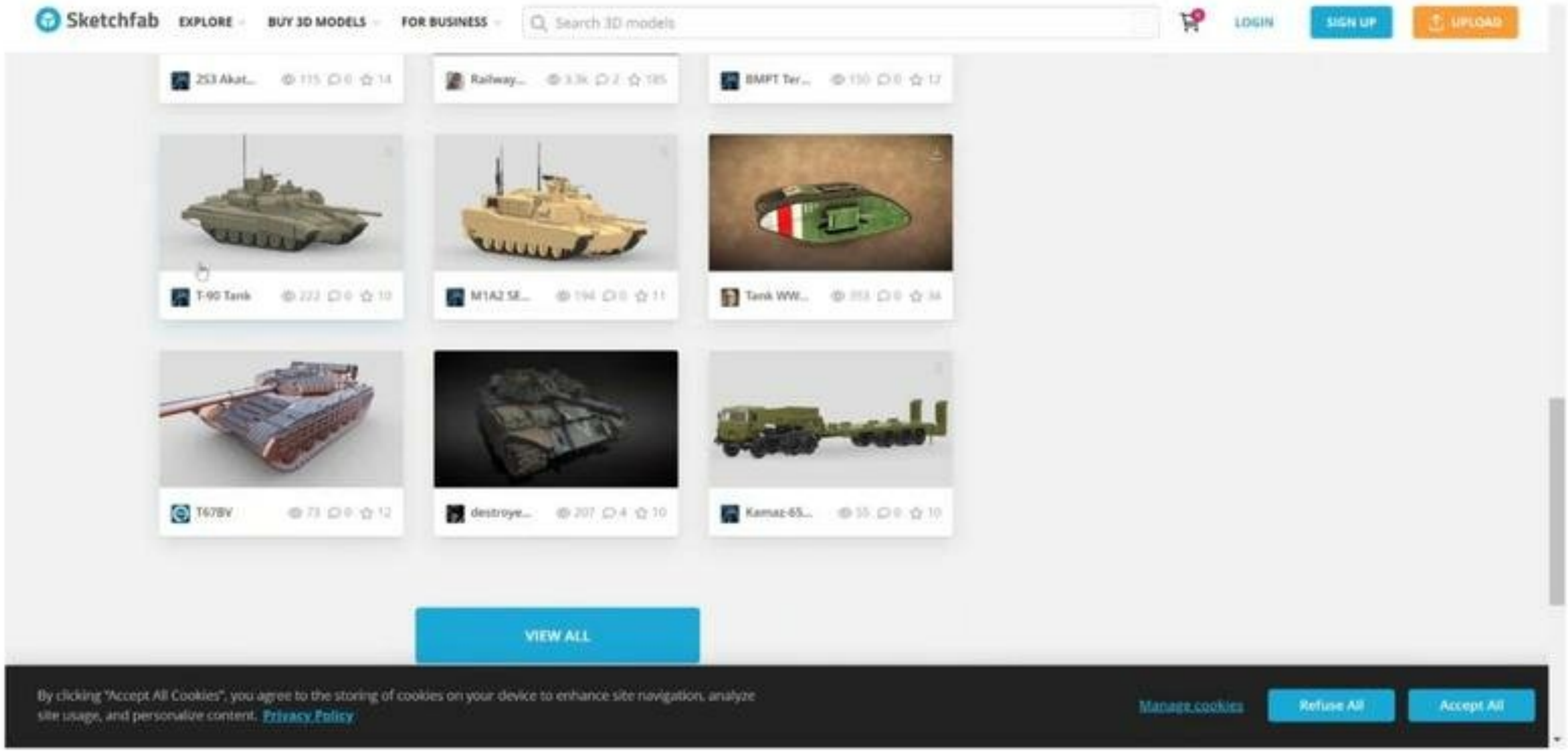
Programs to create 3D models

- Blender
- Tinkercad
- Maya or Maya LT
- 3ds Max
- Cinema4D

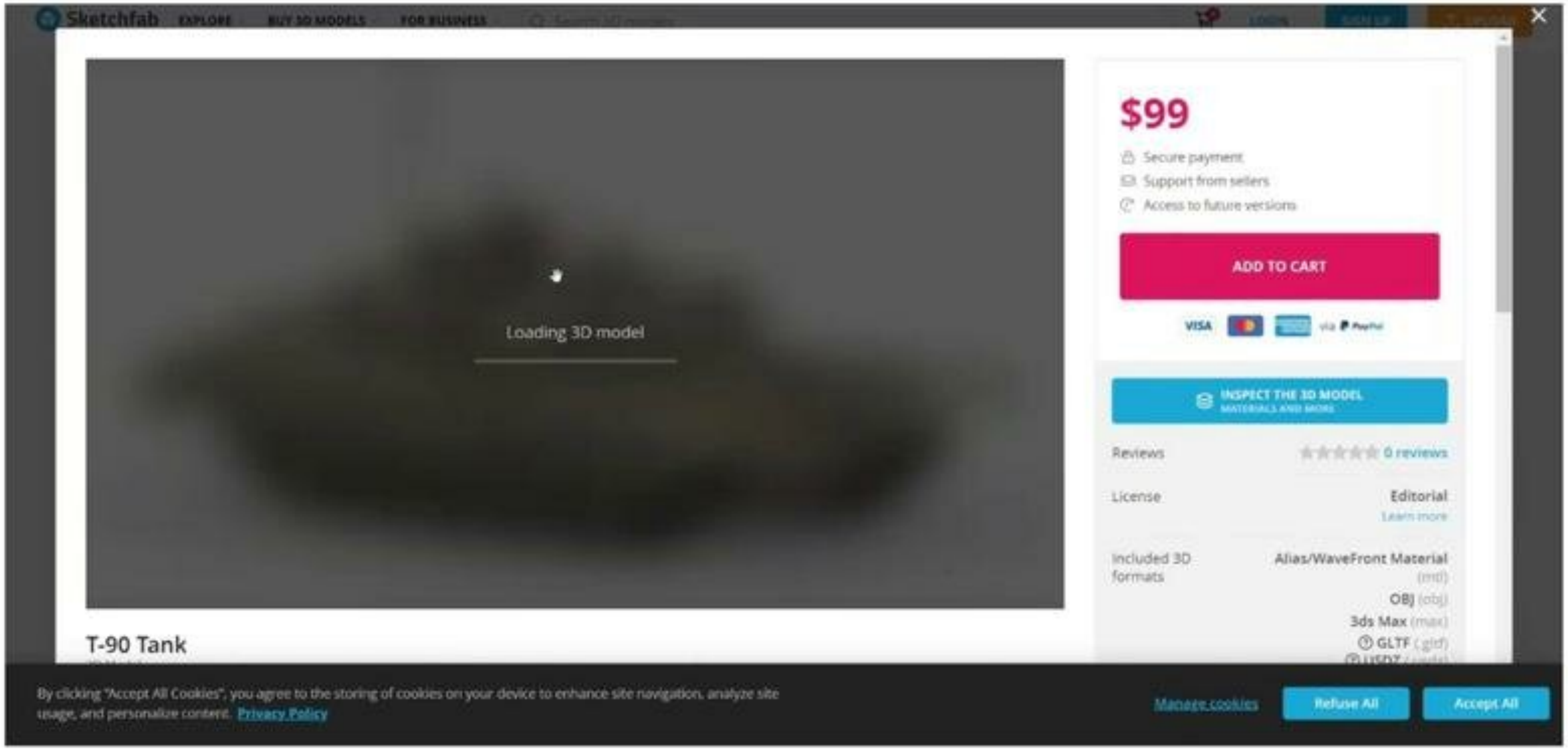
E.g., 3D Model from sketchfab.com



E.g., 3D Model from sketchfab.com



E.g., 3D Model from sketchfab.com

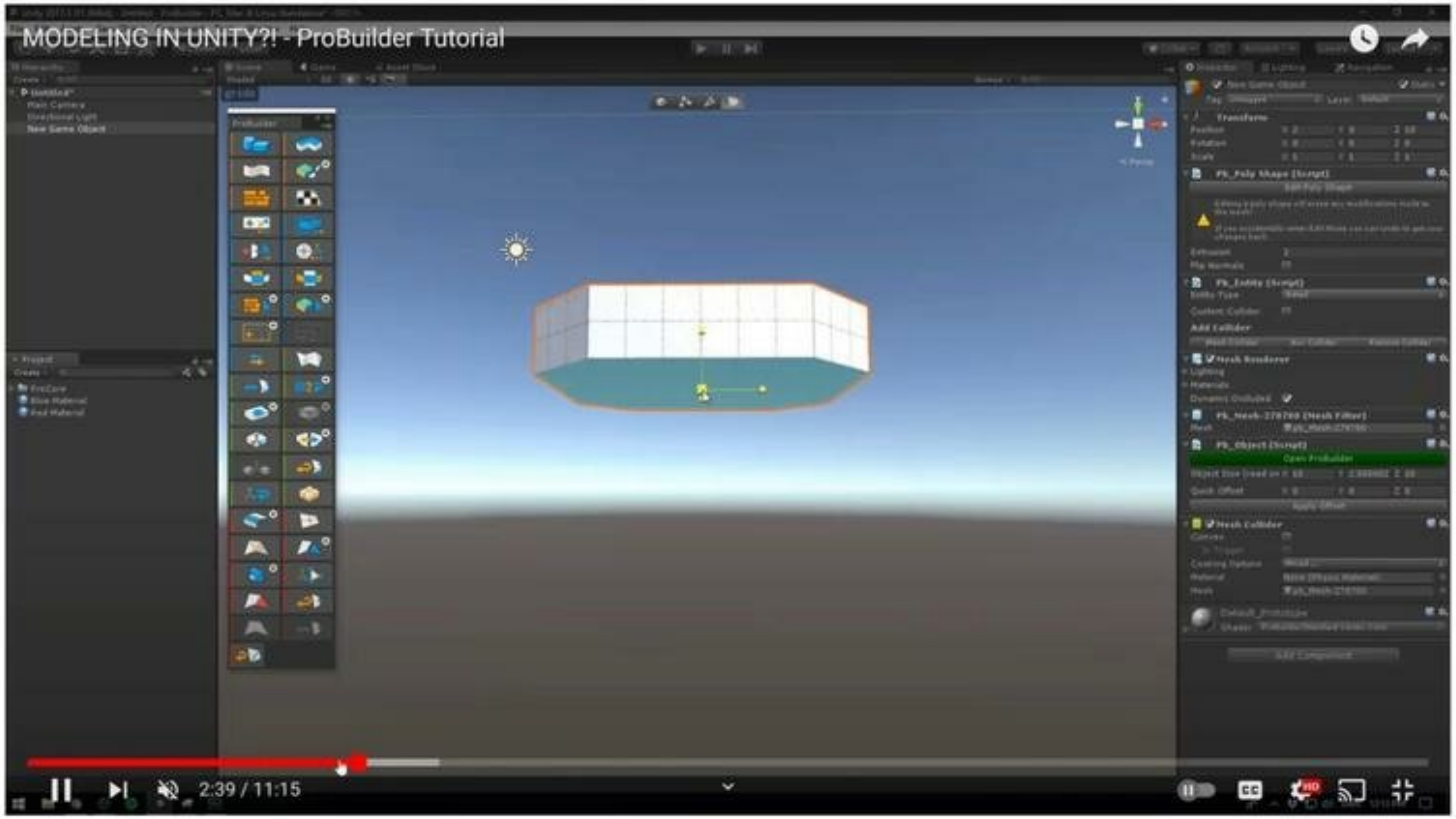


E.g., Import 3D Model to Unity

E.g., Import 3D Model to Unity

E.g., Import 3D Model to Unity

Create Basic 3D Models in Game Engine



Non-Human 3D Objects

3D models consist of

- **Geometry/mesh/skin**
  Vertex positions, normals, & faces, texture coordinates
- **Material**
  Shader, bump/normal/… maps
- **Textures**
  Image sprites
- **Skeleton/rig & animations**
  Bones, poses/keyframes

3D model file formats

Human 3D Objects

Sketchfab

cgtrader

Non-Human 3D Objects

3D models consist of

- **Geometry/mesh/skin**
  Vertex positions, normals, & faces, texture coordinates
- **Material**
  Shader, bump/normal/... maps
- **Textures**
  Image sprites
- **Skeleton/rig & animations**
  Bones, poses/keyframes

3D model file formats

- **glTF** (GL Transmission Format)
  Common on the web
- **fbx** (Autodesk Filmbox)
  Common in Unity and Unreal
- **dae** (Digital Asset Exchange)
- **obj** (Wavefront Object File)
  mtl (Material file with obj)

Human 3D Objects

Sketchfab

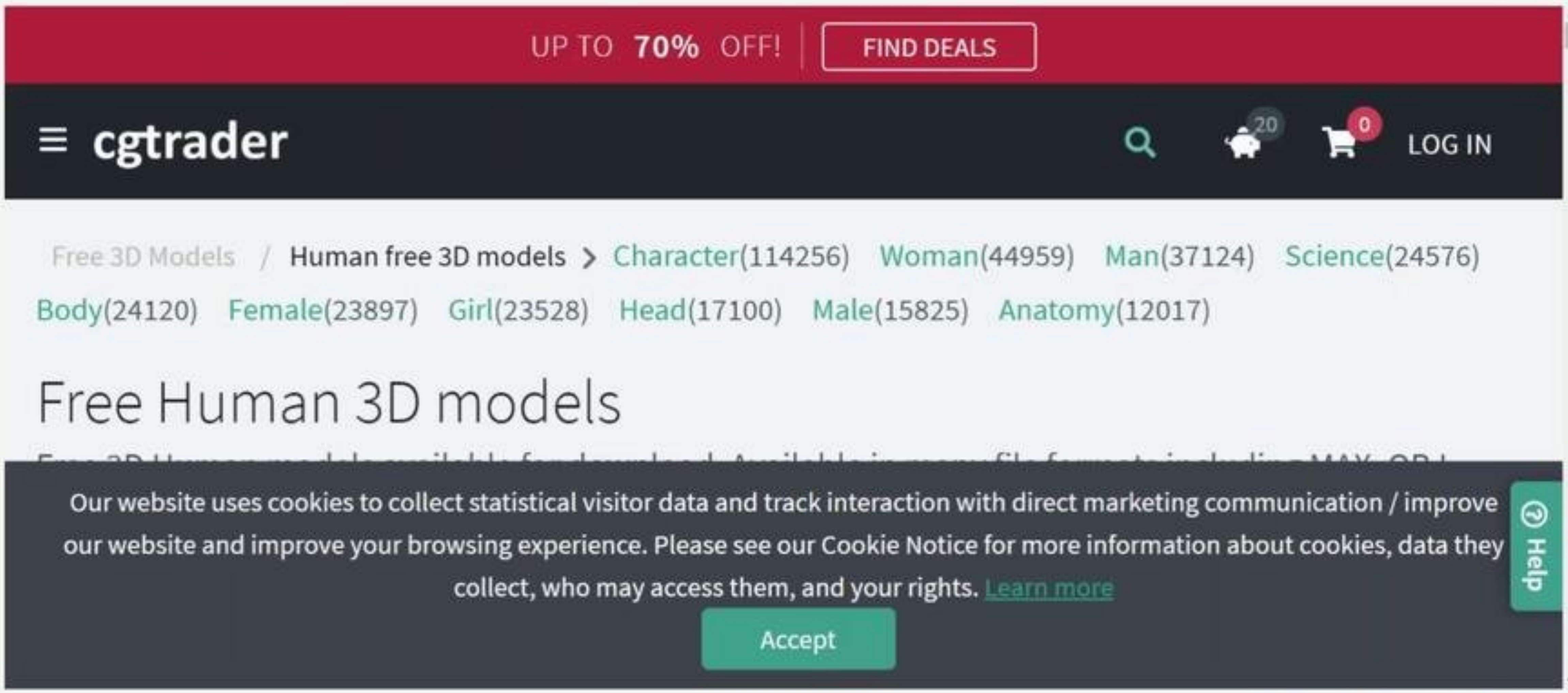
cgtrader

Free3D

TURBOSQUID
by shutterstock

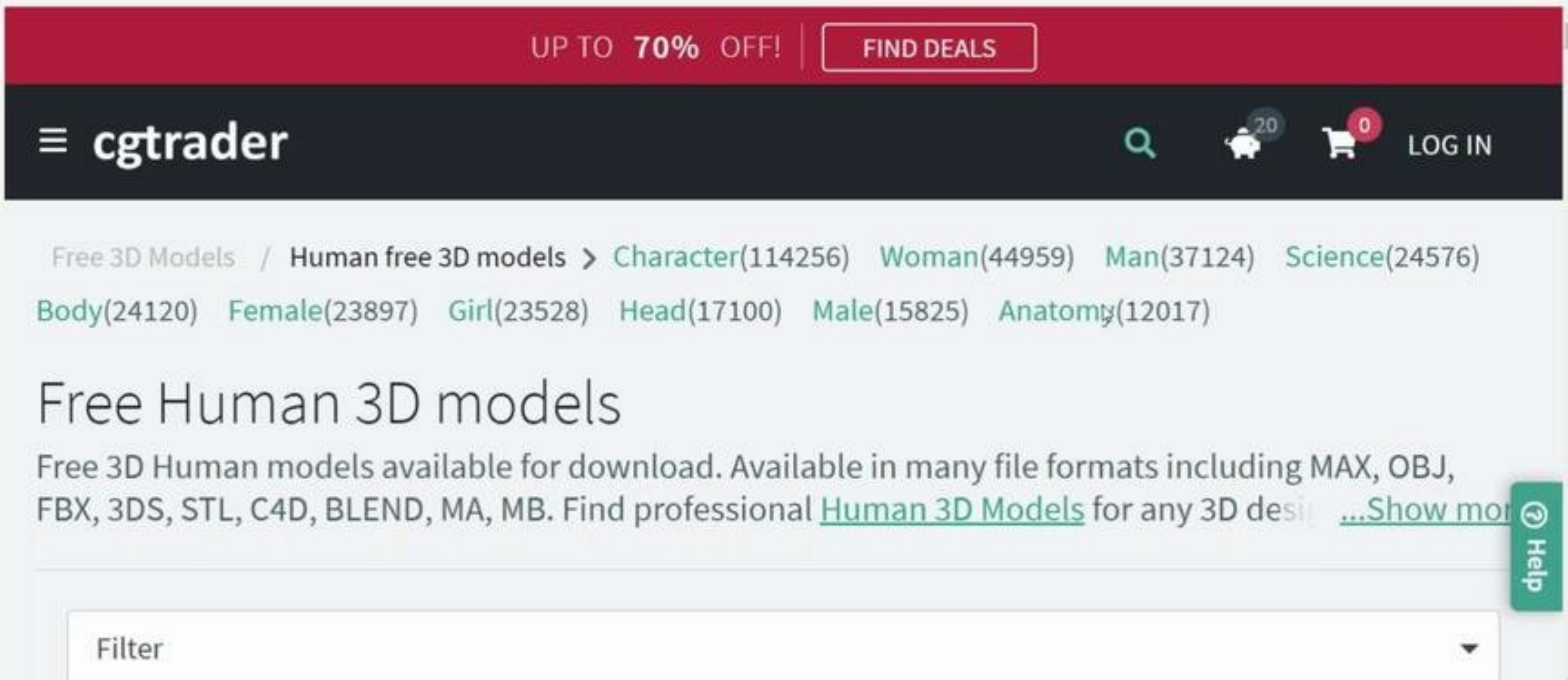
ZYGOTE

Human 3D Objects



Source: https://www.cgtrader.com/free-3d-models/human Web Viewer Terms | Privacy & Cookies

Human 3D Objects



Source: https://www.cgtrader.com/free-3d-models/human

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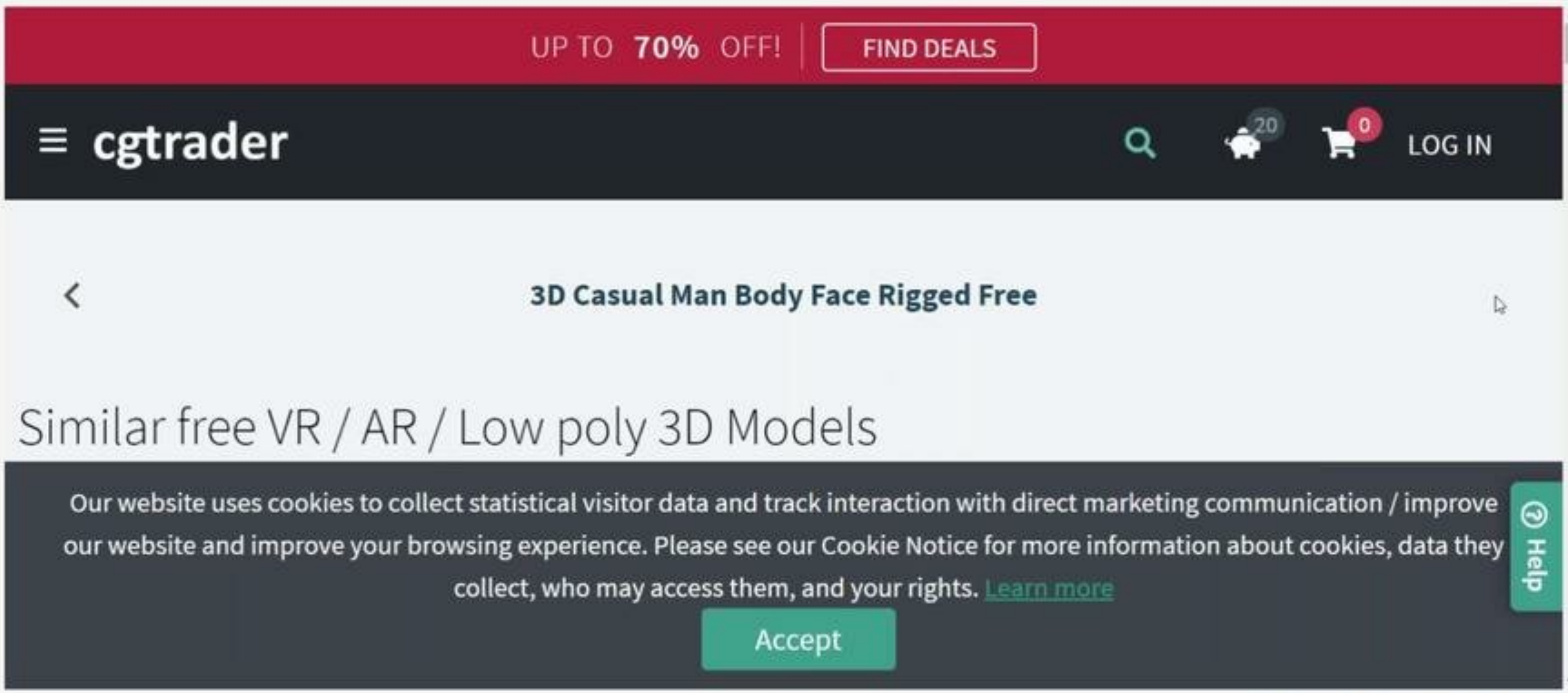
Human 3D Objects



Source: https://www.cgtrader.com/free-3d-models/human

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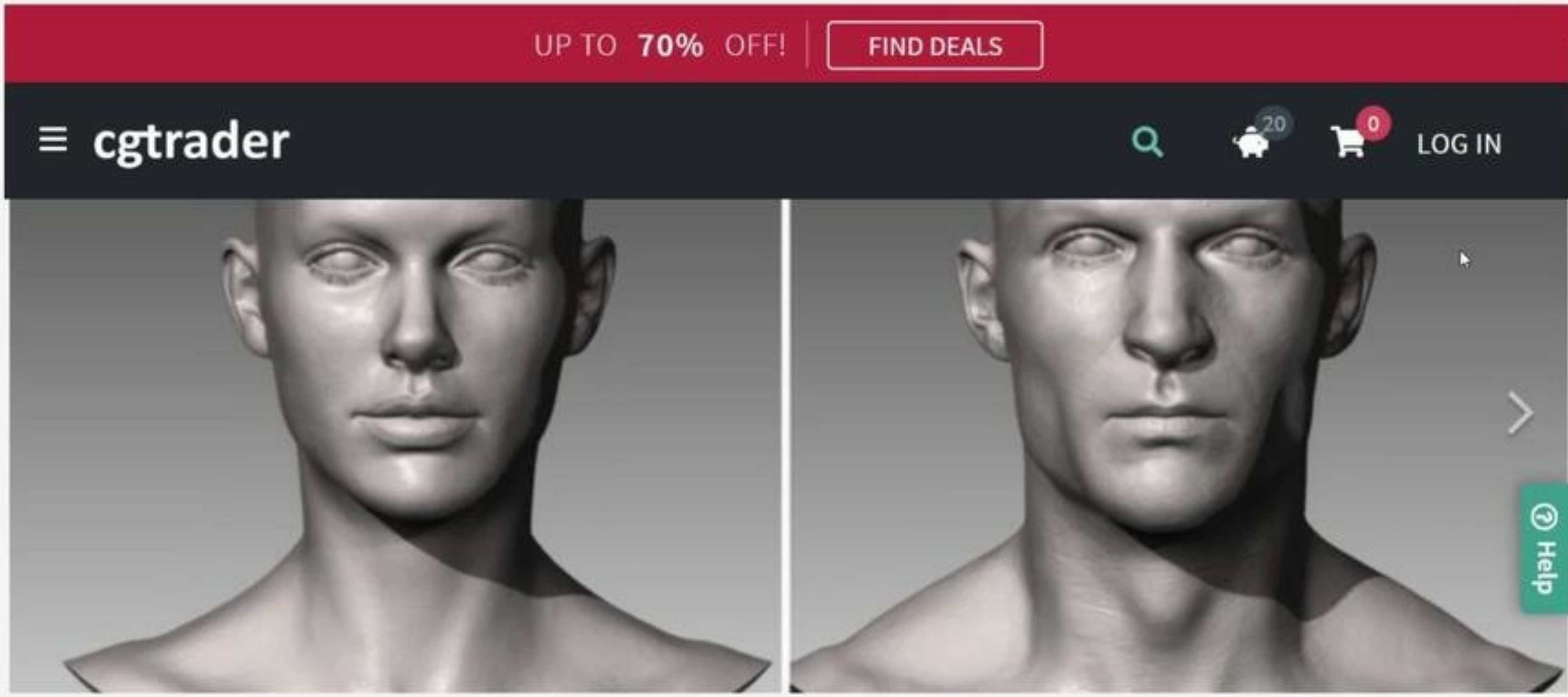
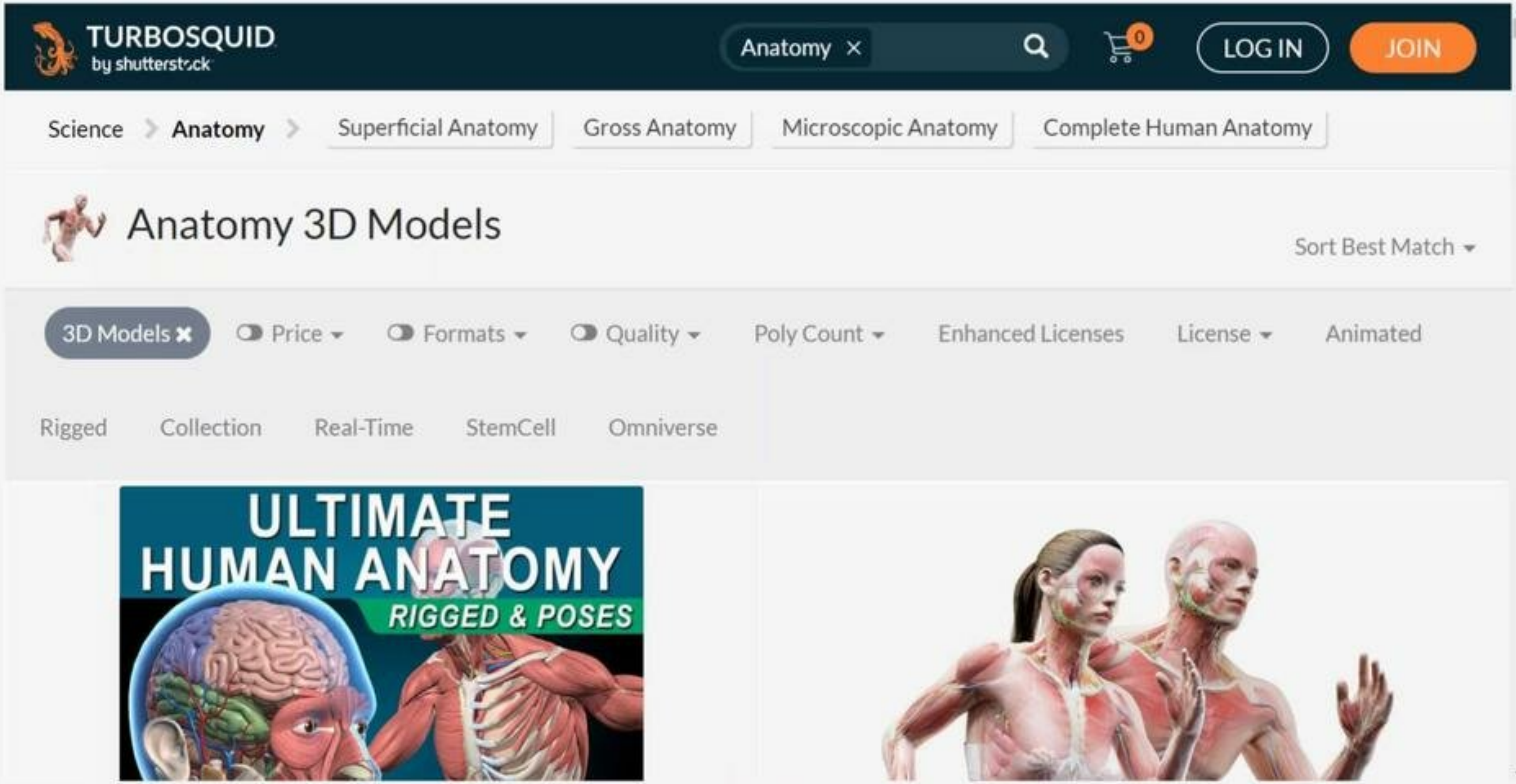
Human 3D Objects



Source: https://www.cgtrader.com/free-3d-models/human



Source: https://www.turbosquid.com/3d-model/anatomy?

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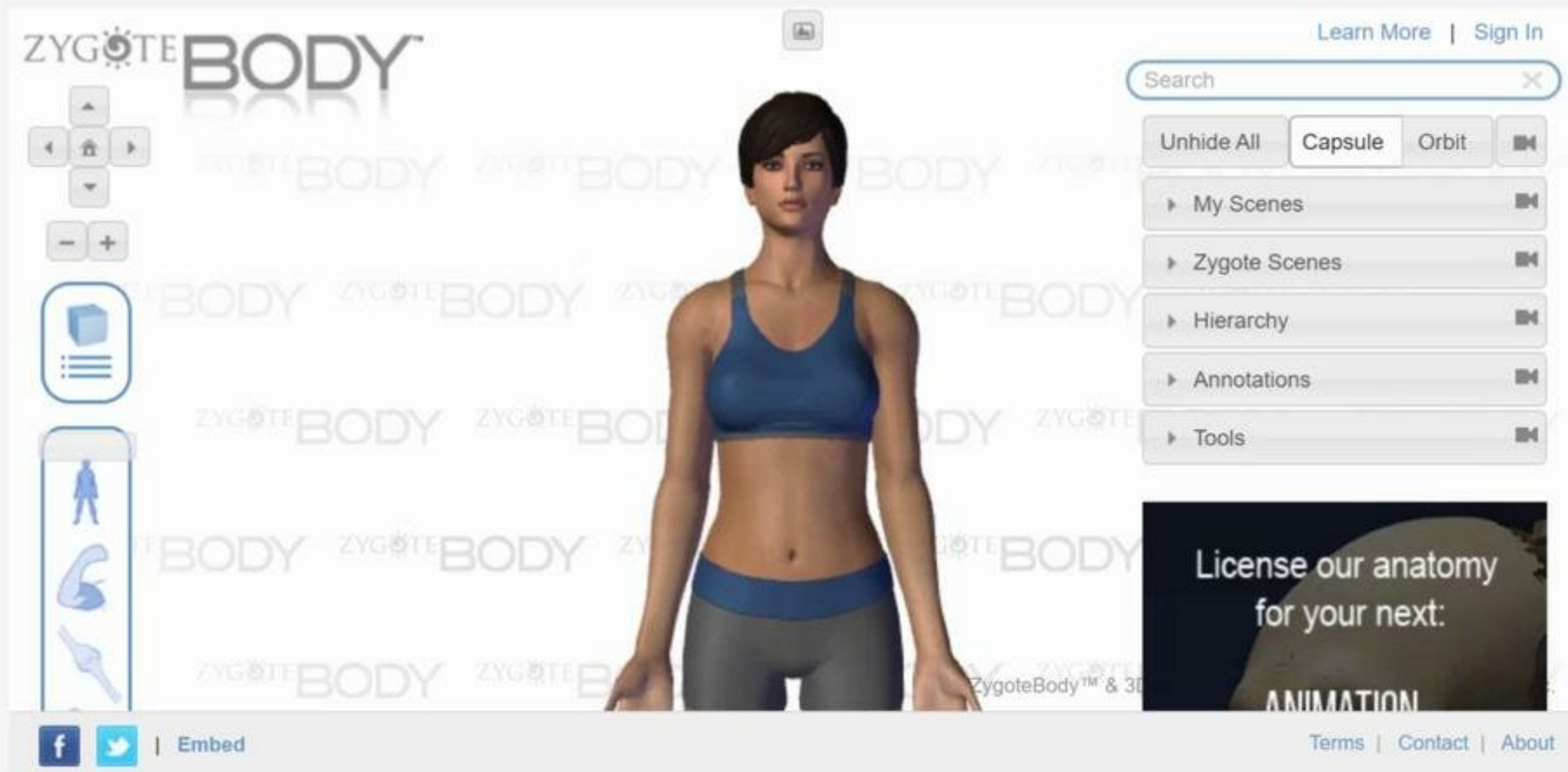

Source: https://www.zygotebody.com/

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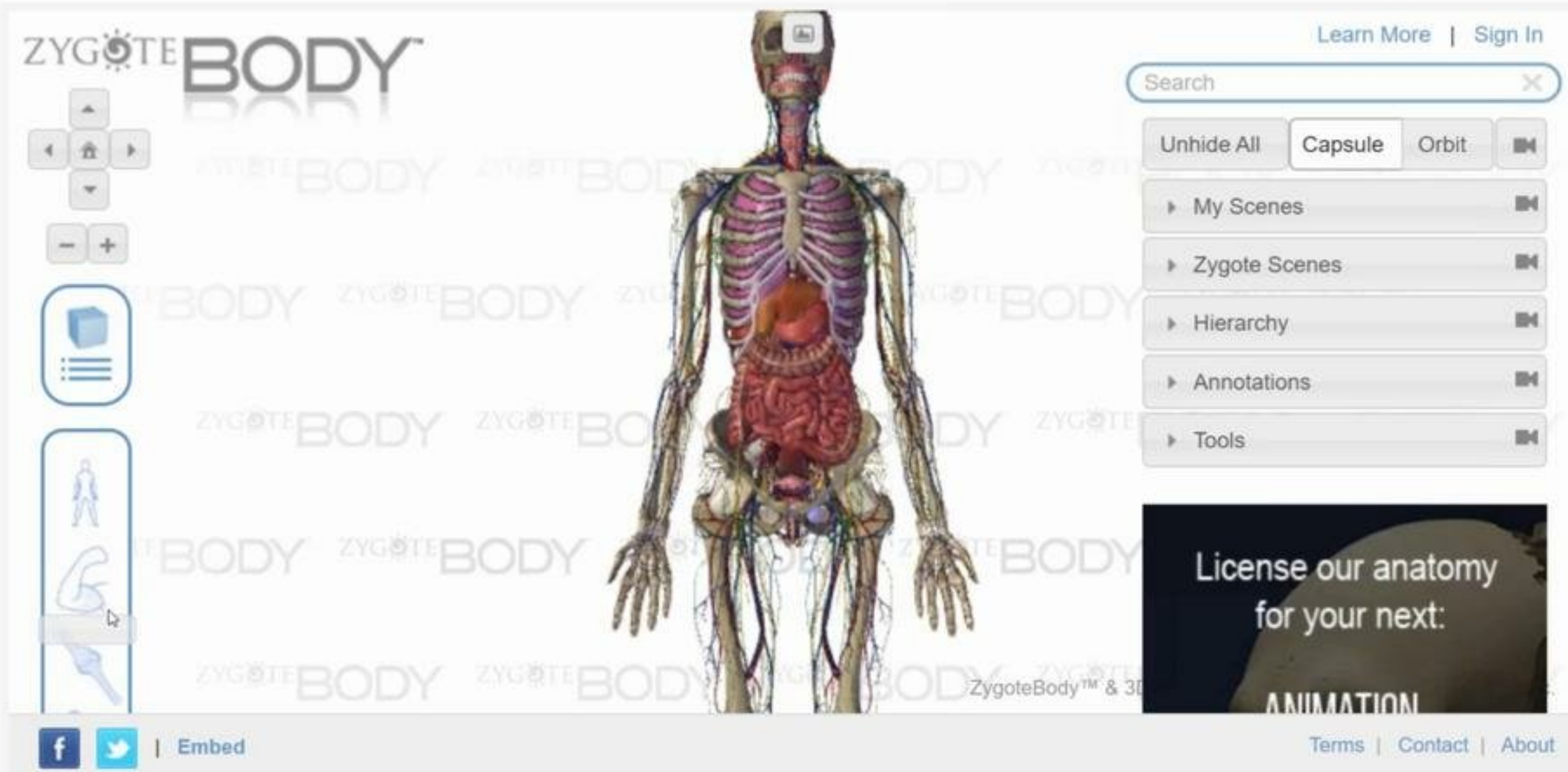

Source: https://www.zygotebody.com/

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Source: https://www.zygotebody.com/

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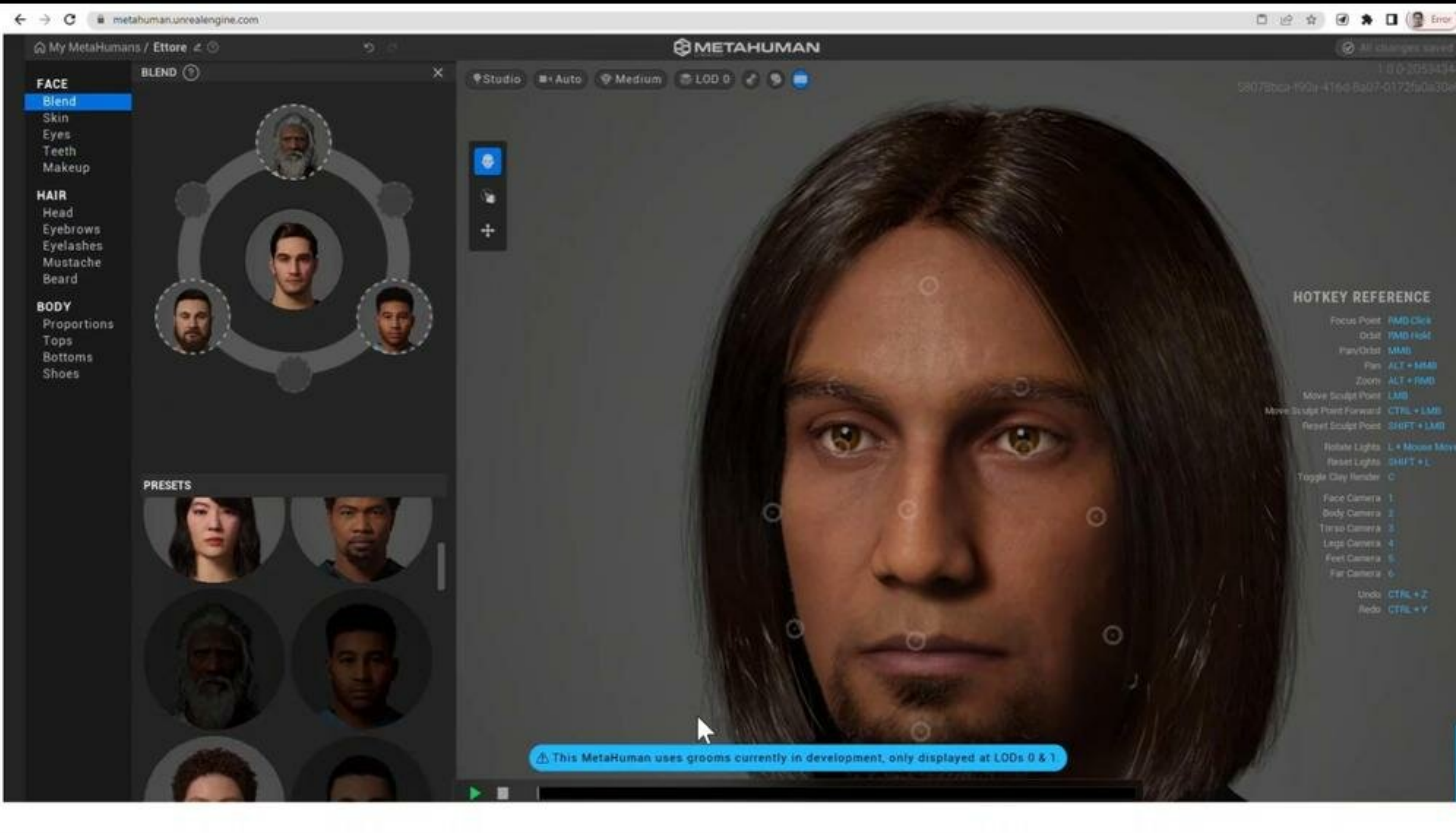
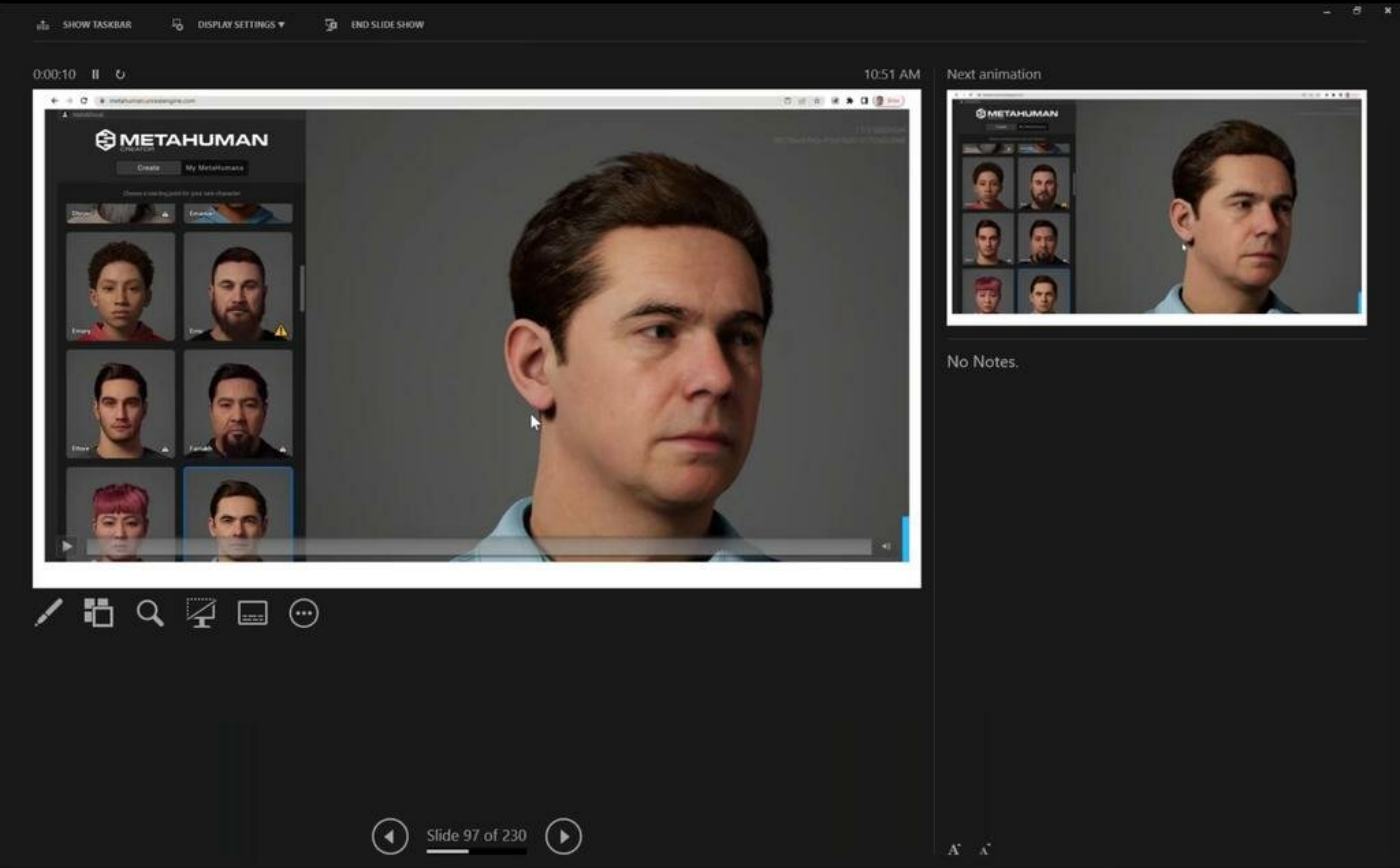

metahuman.unrealengine.com
My MetaHumans / Ettore
METAHUMAN
FACE
Blend
Skin
Eyes
Teeth
Makeup
HAIR
Head
Eyebrows
Eyelashes
Mustache
Beard
BODY
Proportions
Tops
Bottoms
Shoes
BLEND
PRESETS
Studio
Auto
Medium
LOD 0
HOTKEY REFERENCE
This MetaHuman uses grooms currently in development, only displayed at LODs 0 & 1


SHOW TASKBAR
DISPLAY SETTINGS
END SLIDE SHOW
0:00:10
10:51 AM
Next animation
METAHUMAN
Create
My MetaHumans
METAHUMAN
No Notes.
Slide 97 of 230


Metahuman
METAHUMAN
Bridge
Unreal

But! How to Animate Human Models?

Mocap (Motion Capture) Technology

This is where we make digital human live.

Camera-based

Sensor-based

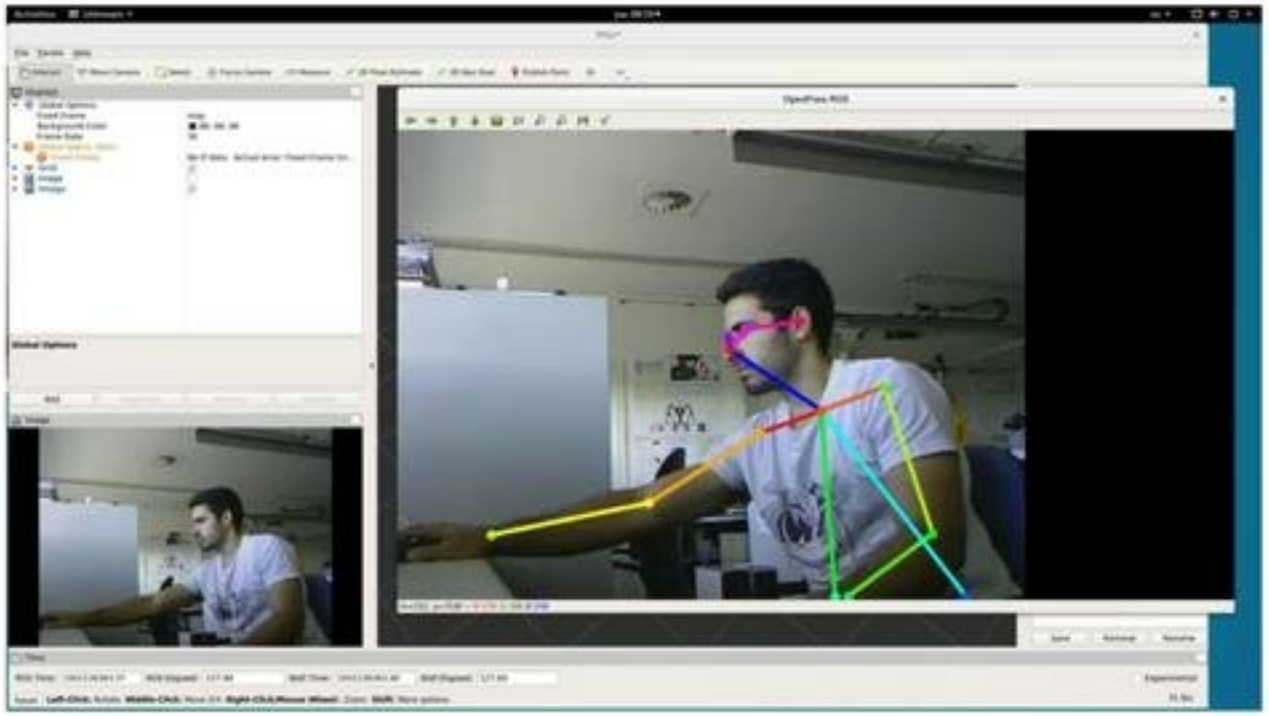
Body Mocap

Camera-based Mocap

Using cameras to capture human movements/skeleton/animation

Open-Pose/ Open CV	**DeepMotion**

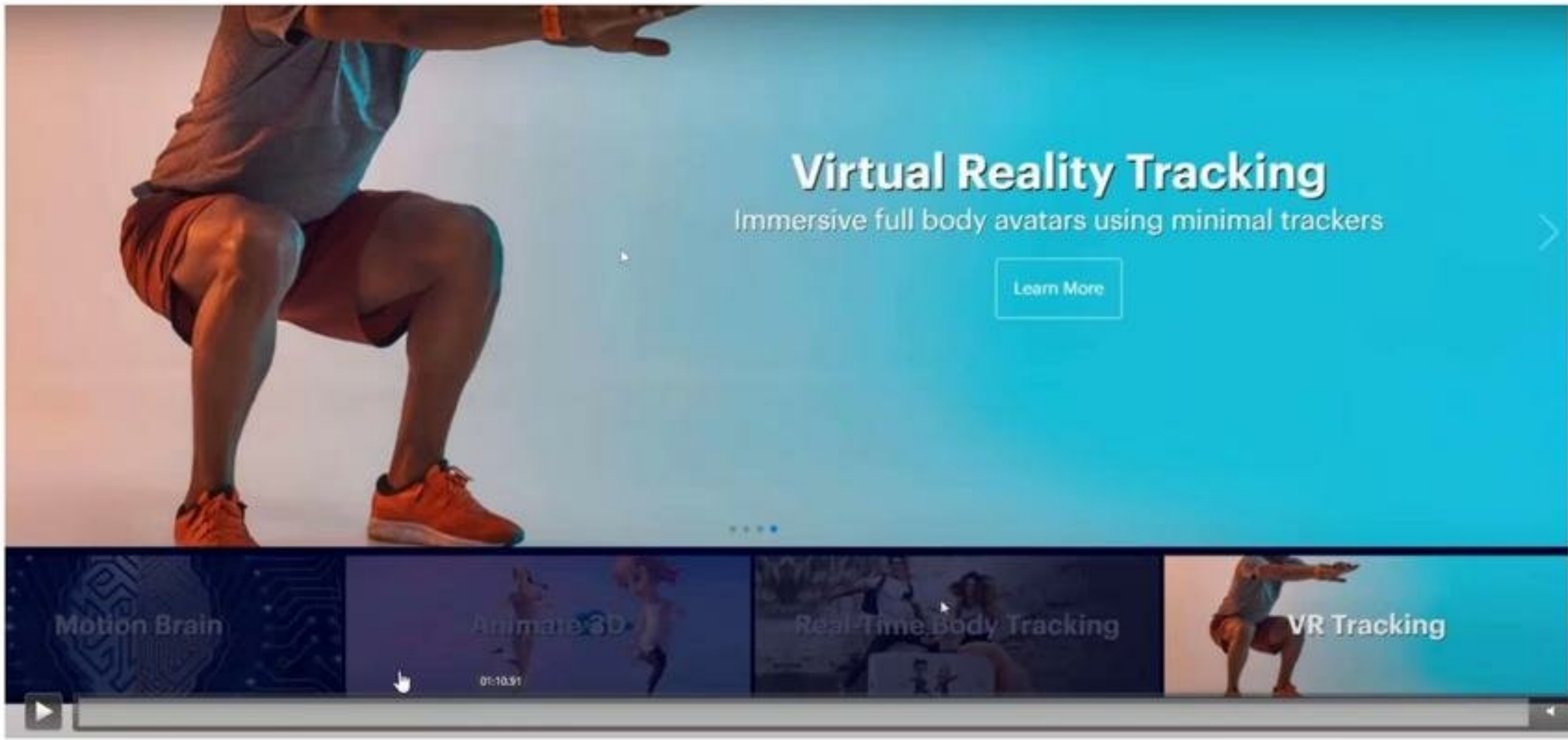
OpenPos



- Free
- Accurate
- Open-source

- Not-intuitive
- Need to be integrated in other system to use
- Need to use your system (CPU/GPU) to process data

DeepMotion


Virtual Reality Tracking
Immersive full body avatars using minimal trackers
Learn More
Motion Brain
Real-Time Body Tracking
VR Tracking

- Easy to use
- No need for technical knowledge
- Perform all pre and post-processing in the cloud

- Need to pay
- Not open-source
- Limited integration capability

Sensor-based Mocap

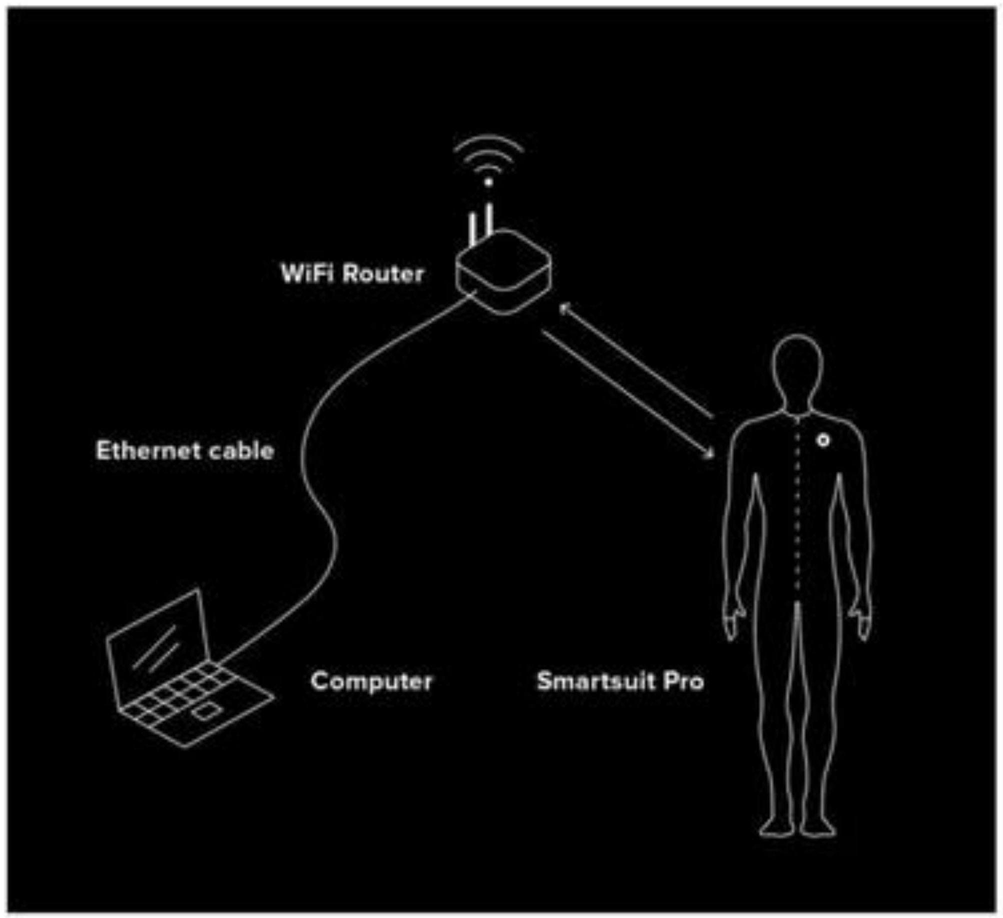
Using sensors to capture human movements/skeleton/animation

Smart Suits

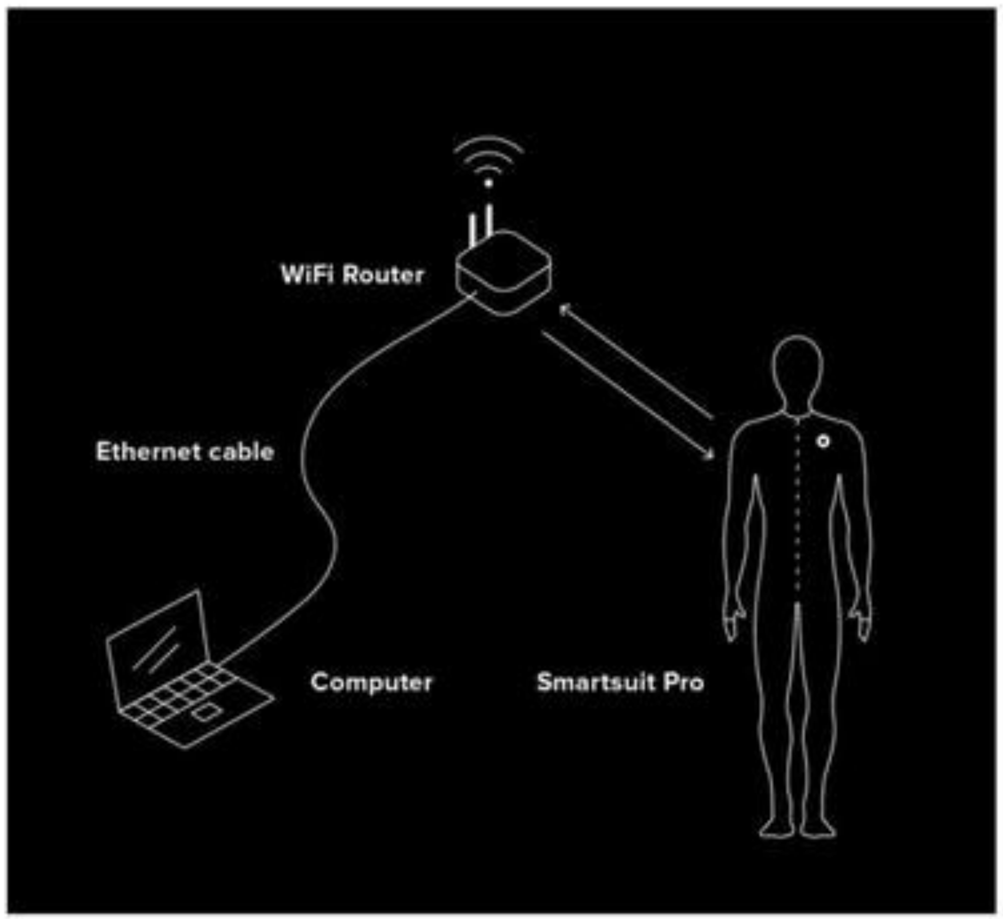
Individual Sensors

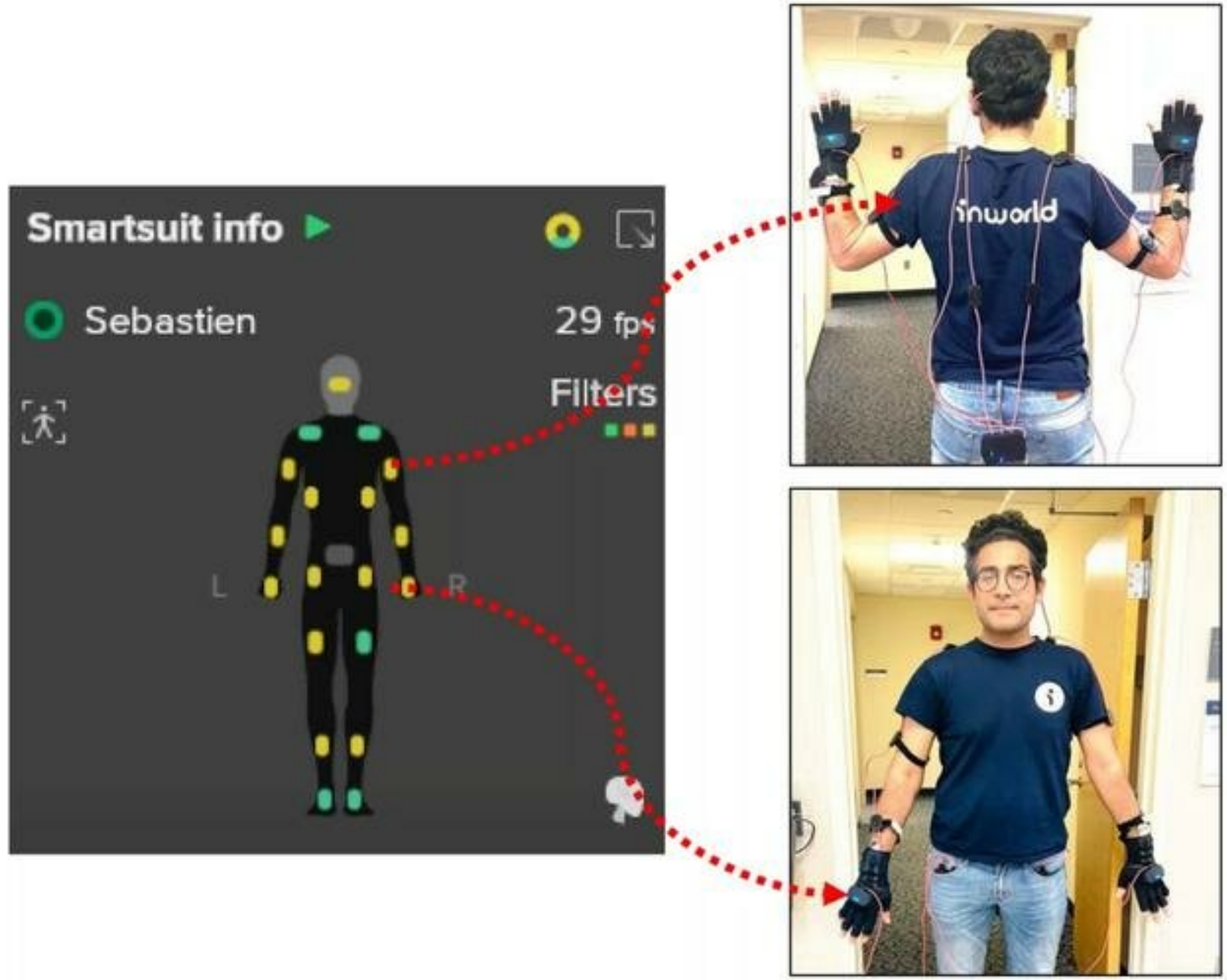
Mocap Suit: Rokoko

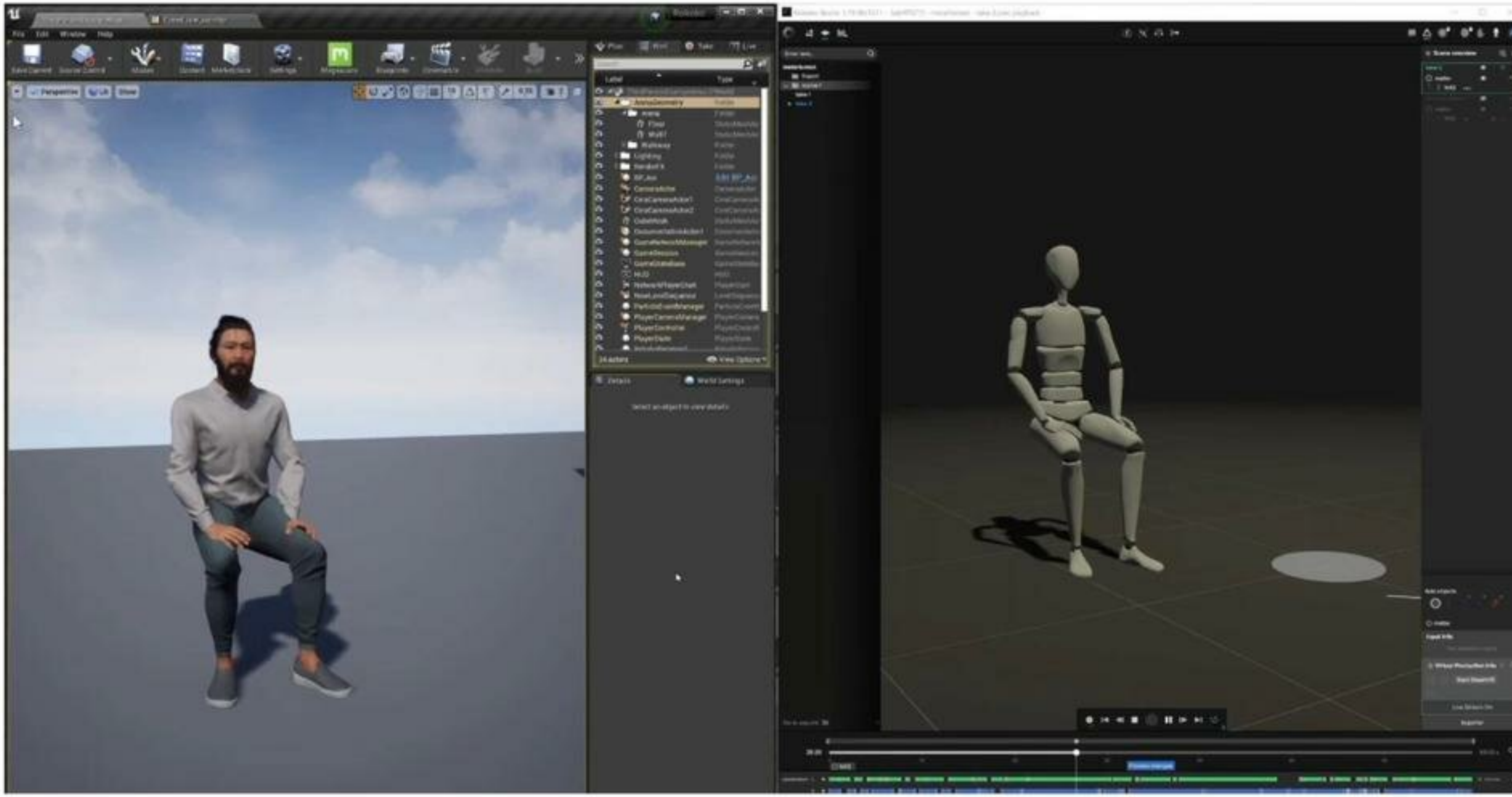
Rokoko: what is inside?



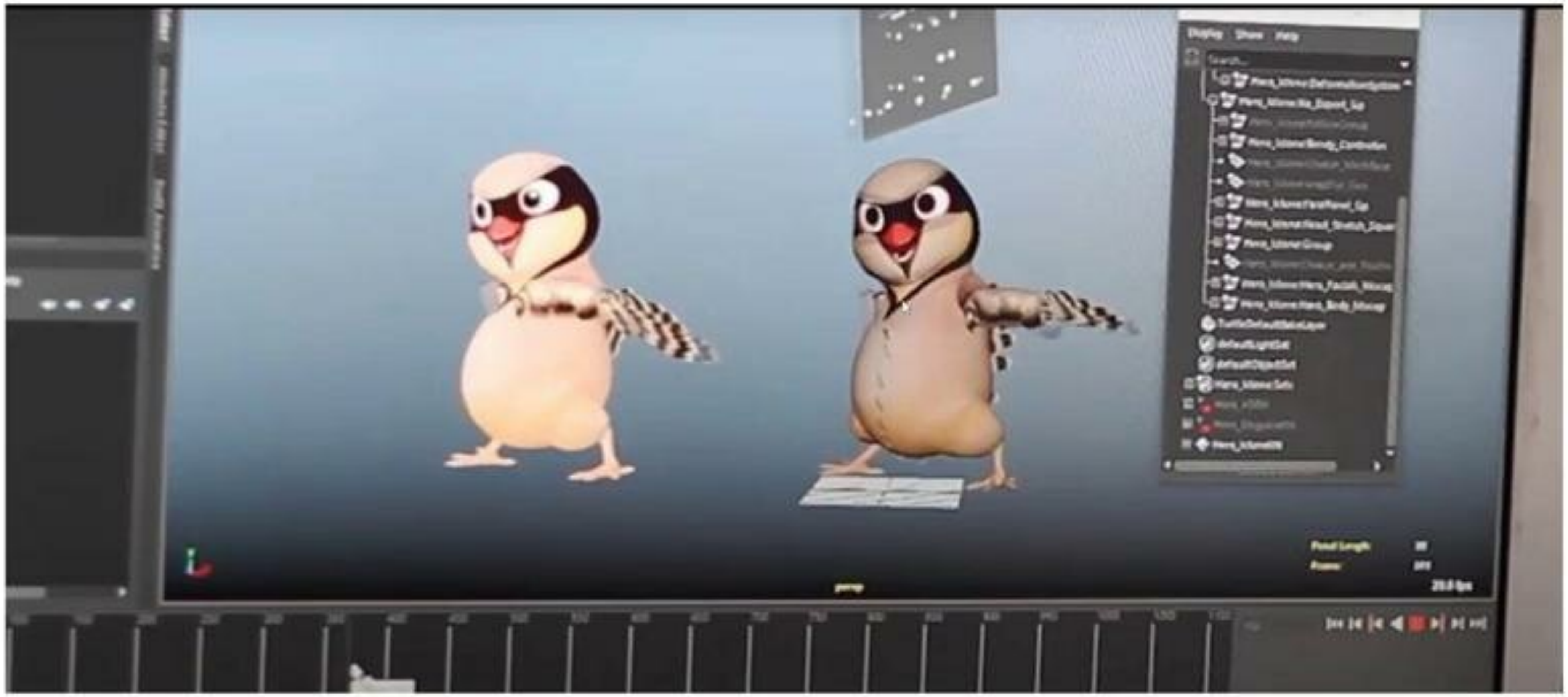
Rokoko: what is inside?







Body and Face Mocap: Xsens



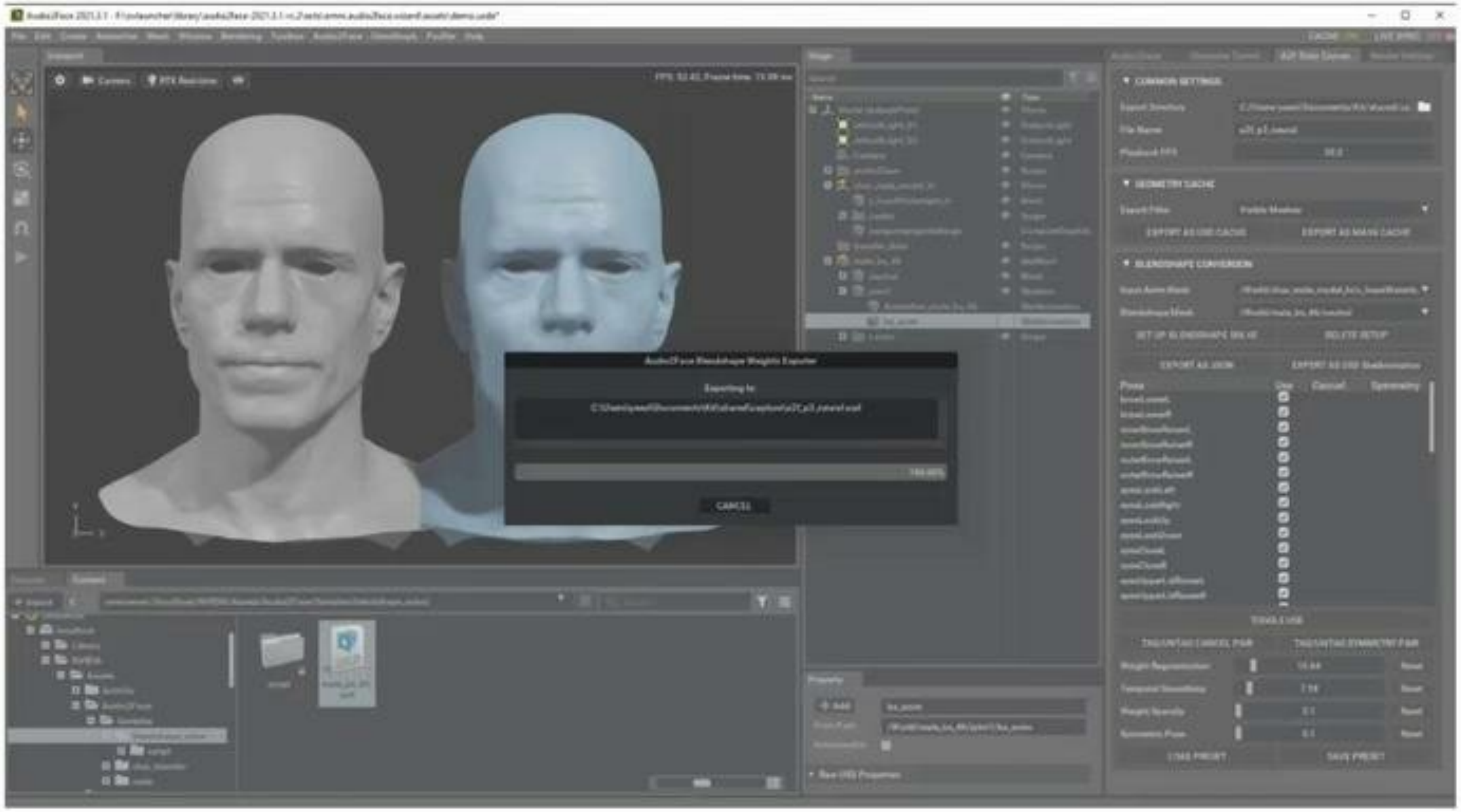
Face Mocap

Face Mocap: Camera with TrueDepth feature (used for face ID)

Face Mocap: Camera with TrueDepth feature (used for face ID)

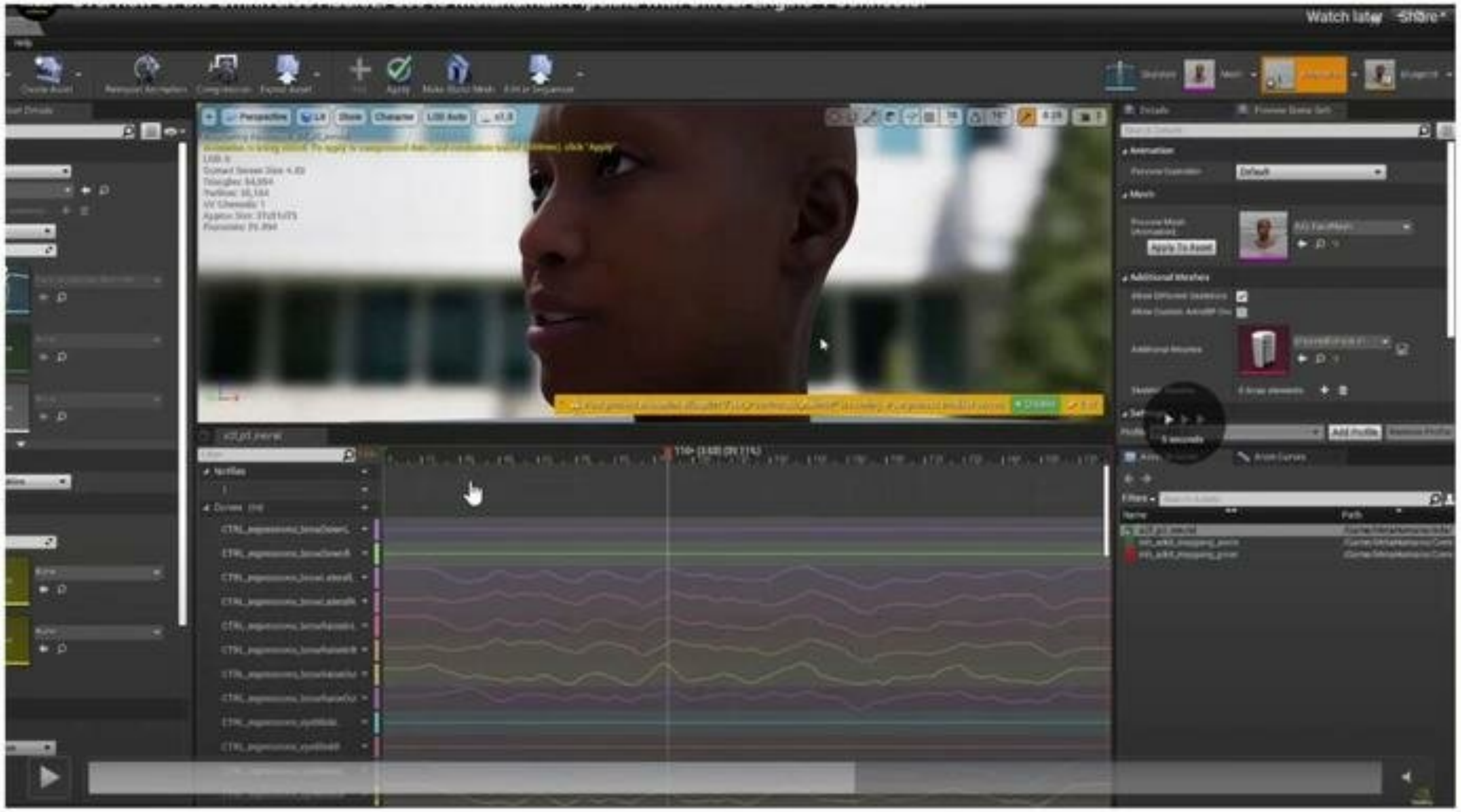
Face Mocap: Live Link App + Unreal

Face Mocap: NVIDIA Omniverse + Unreal



NVIDIA Omniverse

Face Mocap: NVIDIA Omniverse + Unreal



NVIDIA Omniverse

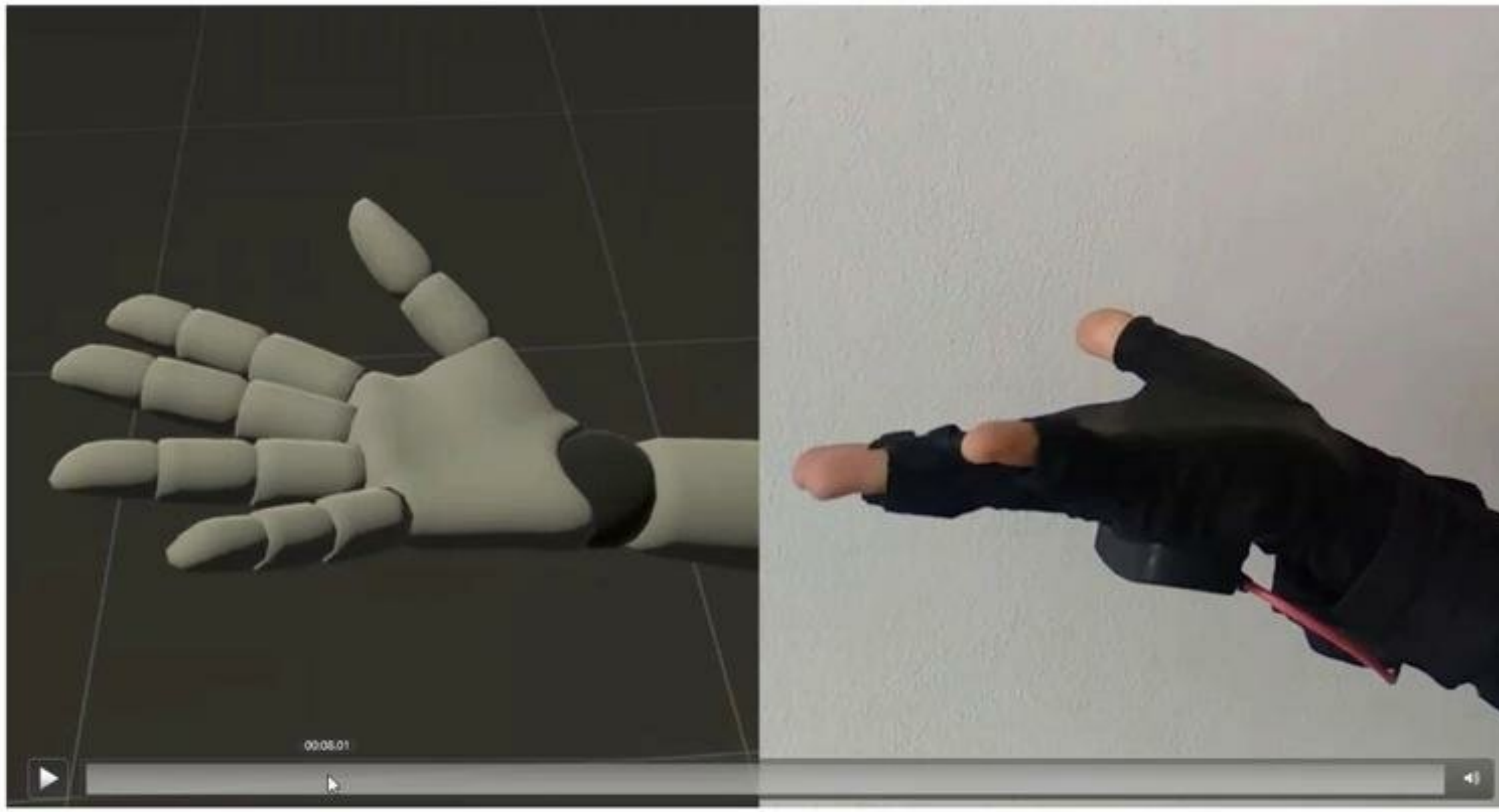
Hand Mocap

Hand Mocap: Manus

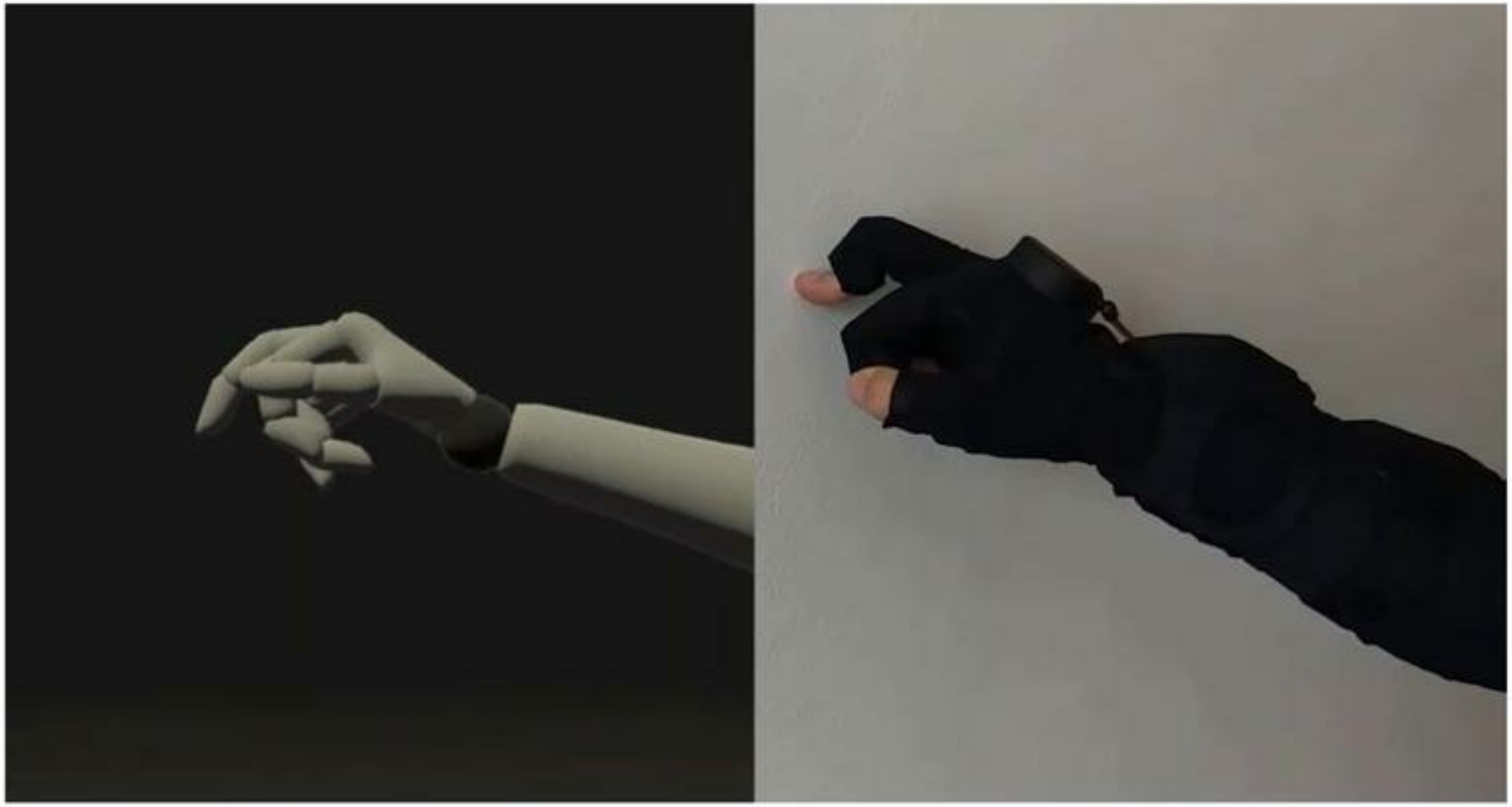
Hand Mocap: Manus

Hand Mocap: Manus

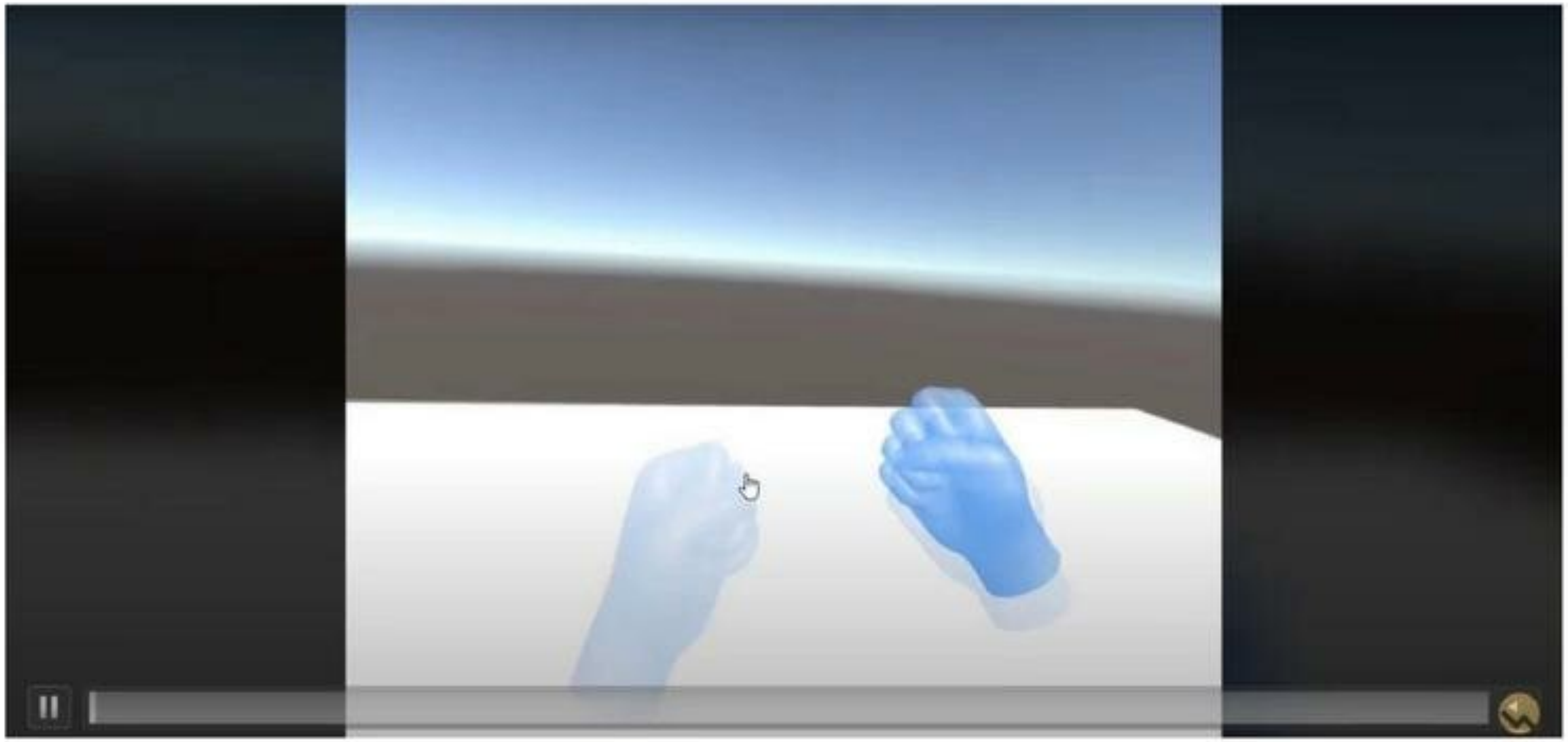
Hand Mocap: Rokoko



Hand Mocap: Rokoko



Oculus Hand Tracking

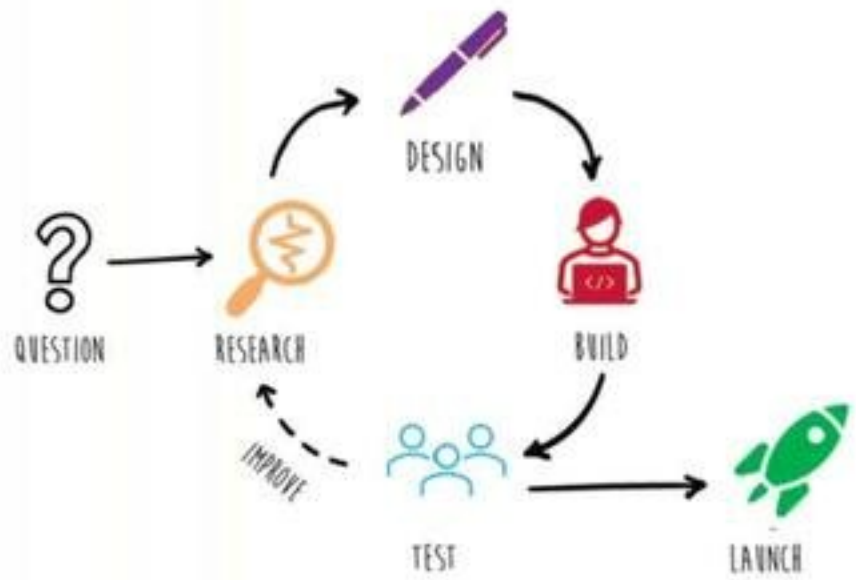


Mocap Using Individual Sensors

Mocap: Using Individual Sensors (HTC Viv)

Recap!

Recap!



Recap!

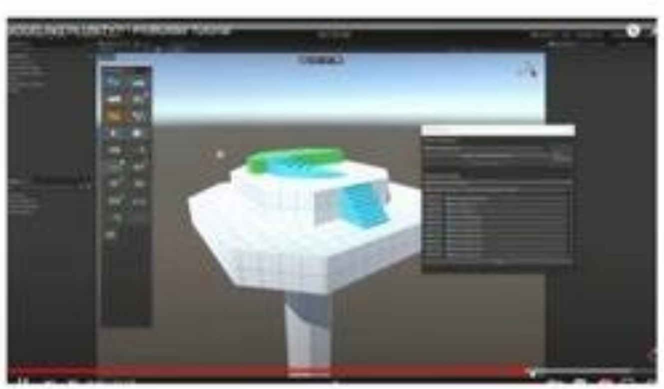
Design Elements

What are? How to get / create?

Scenarios / Stories

miro

Non-human 3D Objects



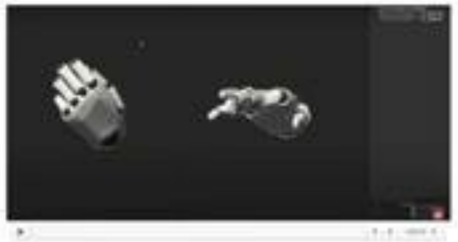
Human 3D Objects

Recap!

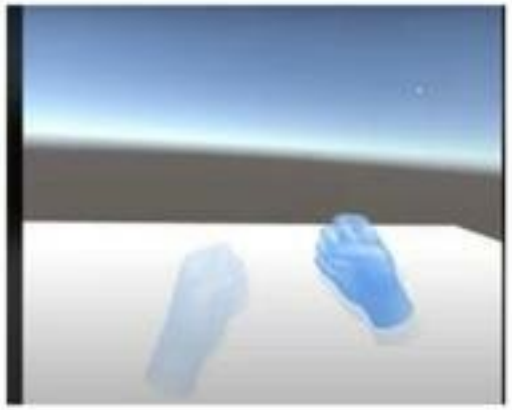
Body Mocap

Face Mocap

Hand Mocap



Oculus Hand Tracking



UIs and Menu

UIs and Menu

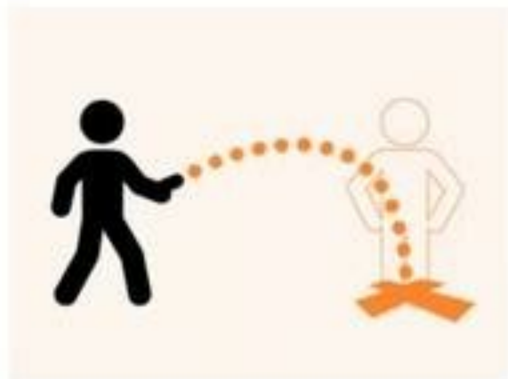
Fixed Anchored in the world	**HUD** Attached to the head (camera)	**Controller** Attached to the tracked controller	**Hand** Attached to the tracked hand

Room setup

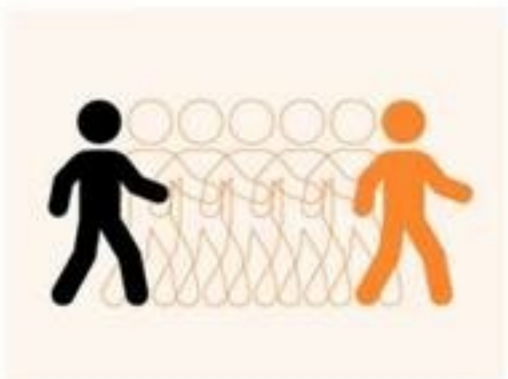
ROOMSCALE

SITTING & STANDING

Movement



TELEPORT



SHIFT

CONTINUOUS

Object Selection

Travel
Moving the viewpoint in the world

Object Selection
Picking objects in the world

Object Manipulation
Modifying objects in the world

Far

Use raycasting and hit-testing for object selection

Near

Use collision detection for object selection

XR Design Issues?

Social & Ethical Concerns

Accessibility & Equity

Privacy & Security

Design Ethics

What when users can't tell what's real and what's virtual anymore?

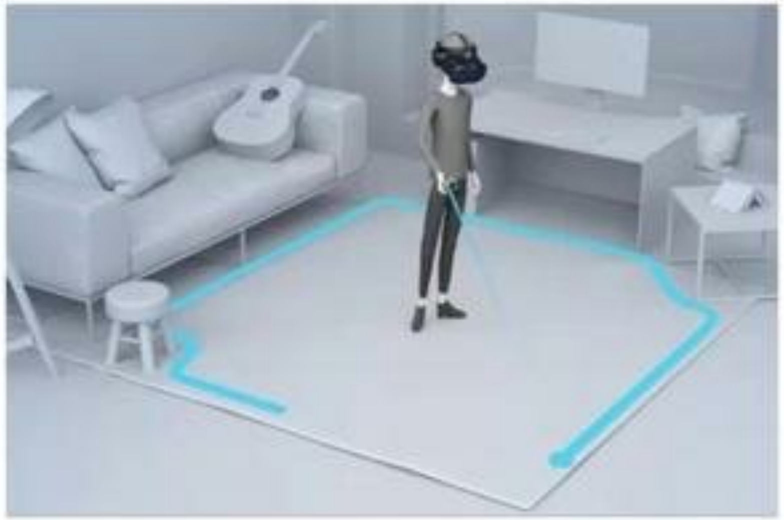
How do we hold XR designers accountable?

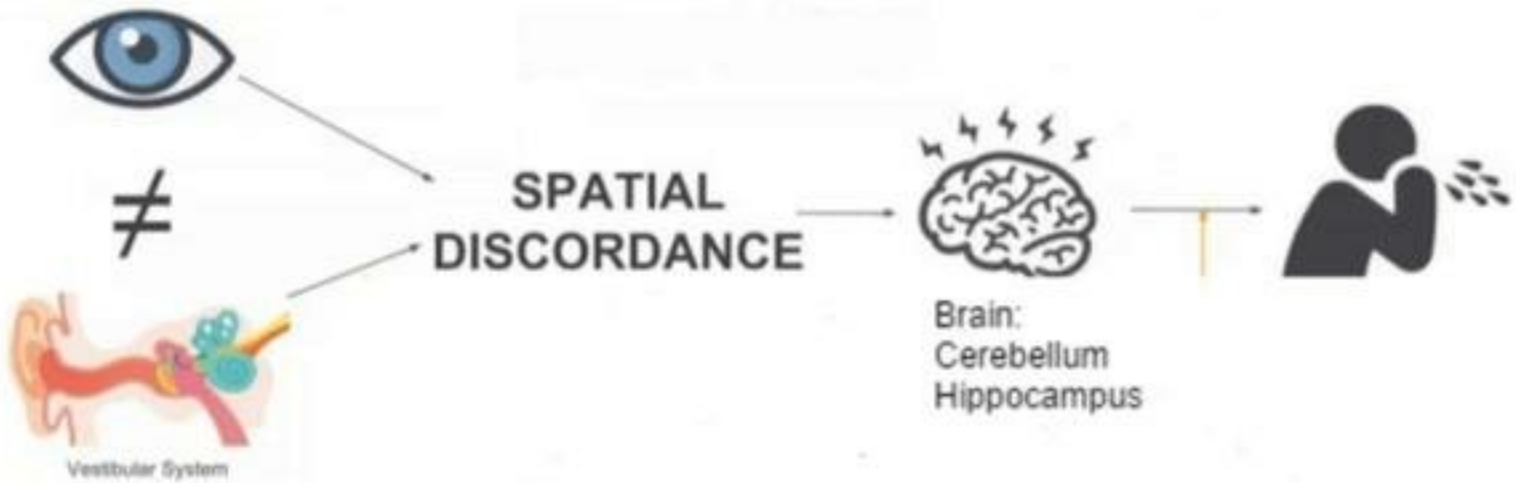
What are good ethics principles of XR design?

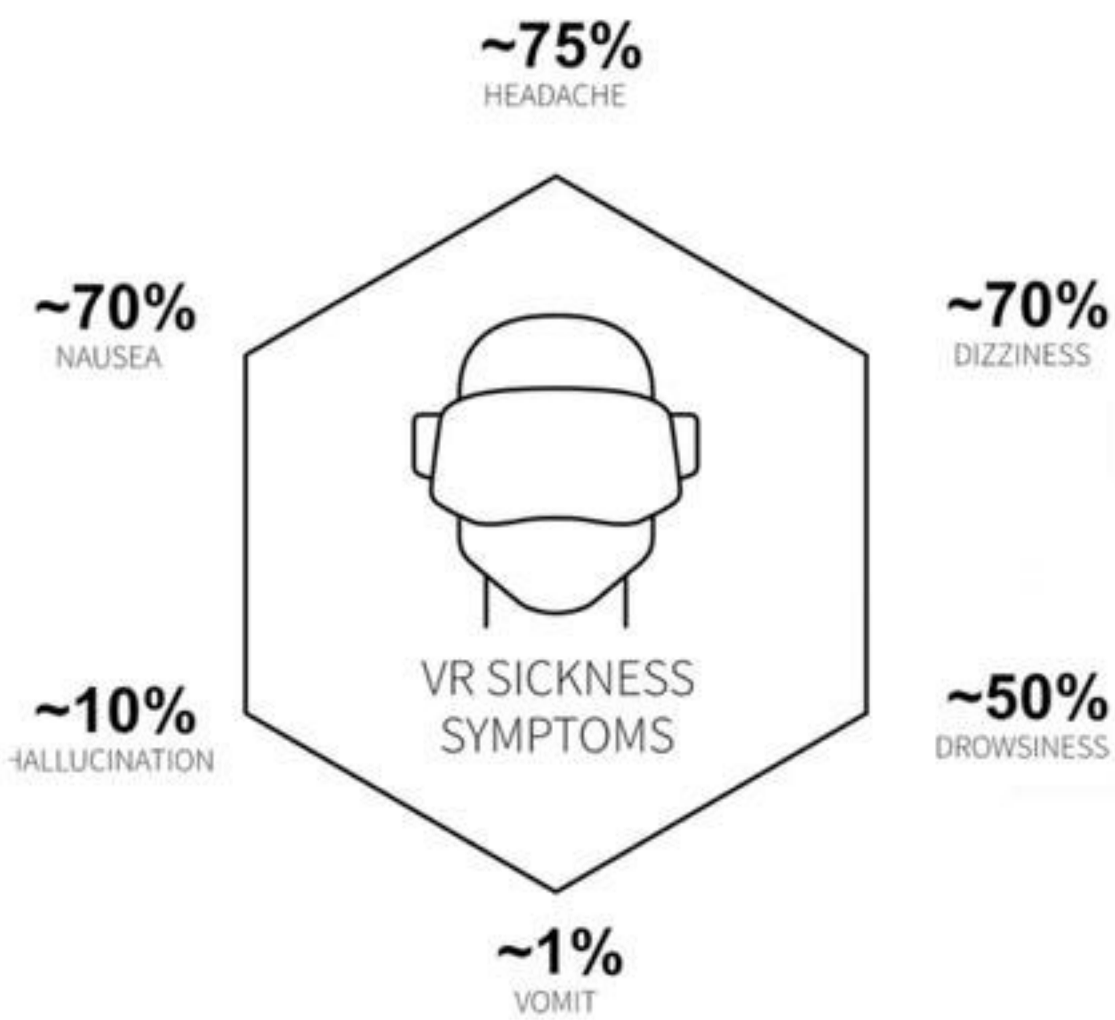
What is the role and responsibility of the XR designer?

What happens when users go against our intended design?

Motion Sickness



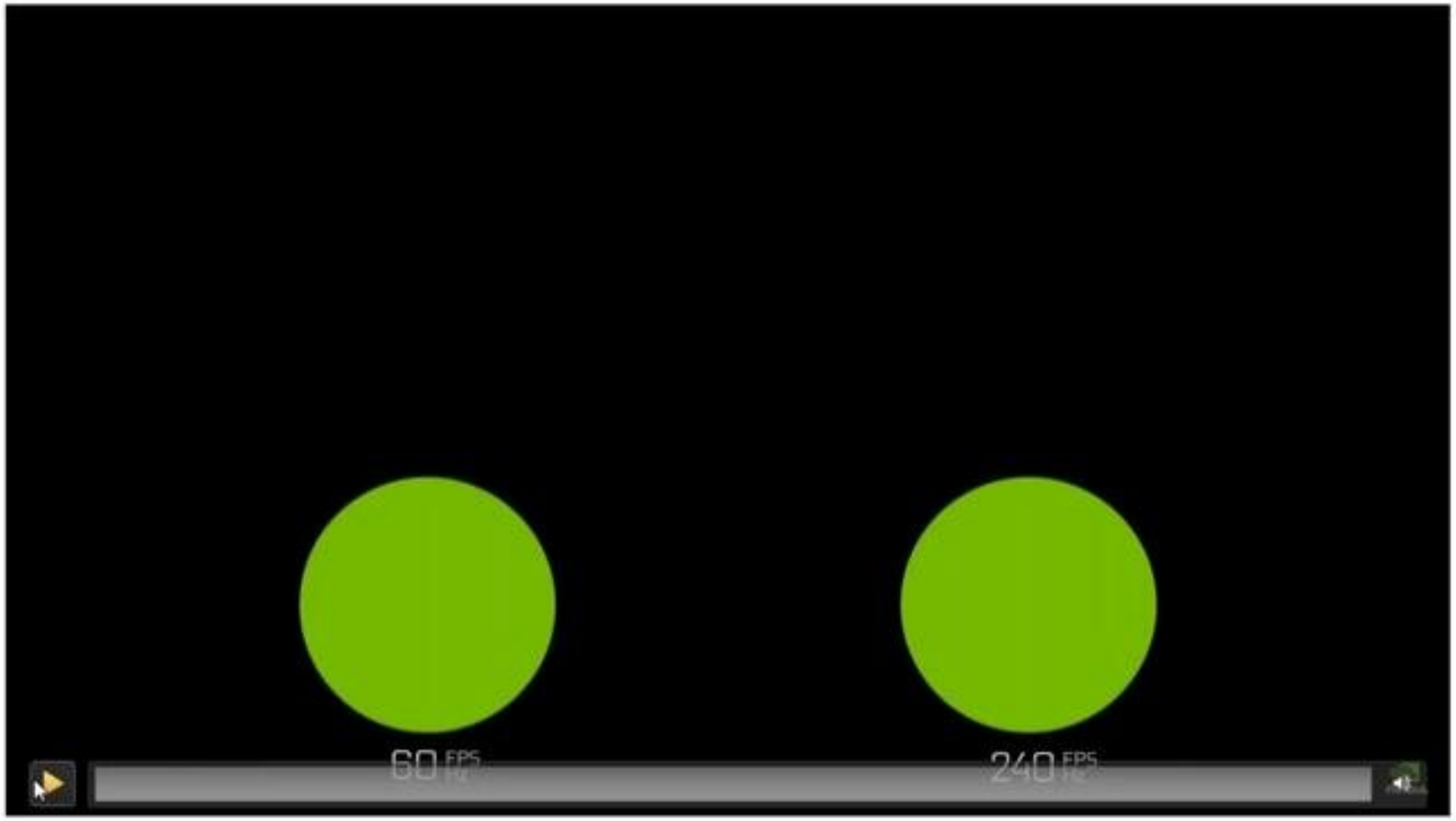




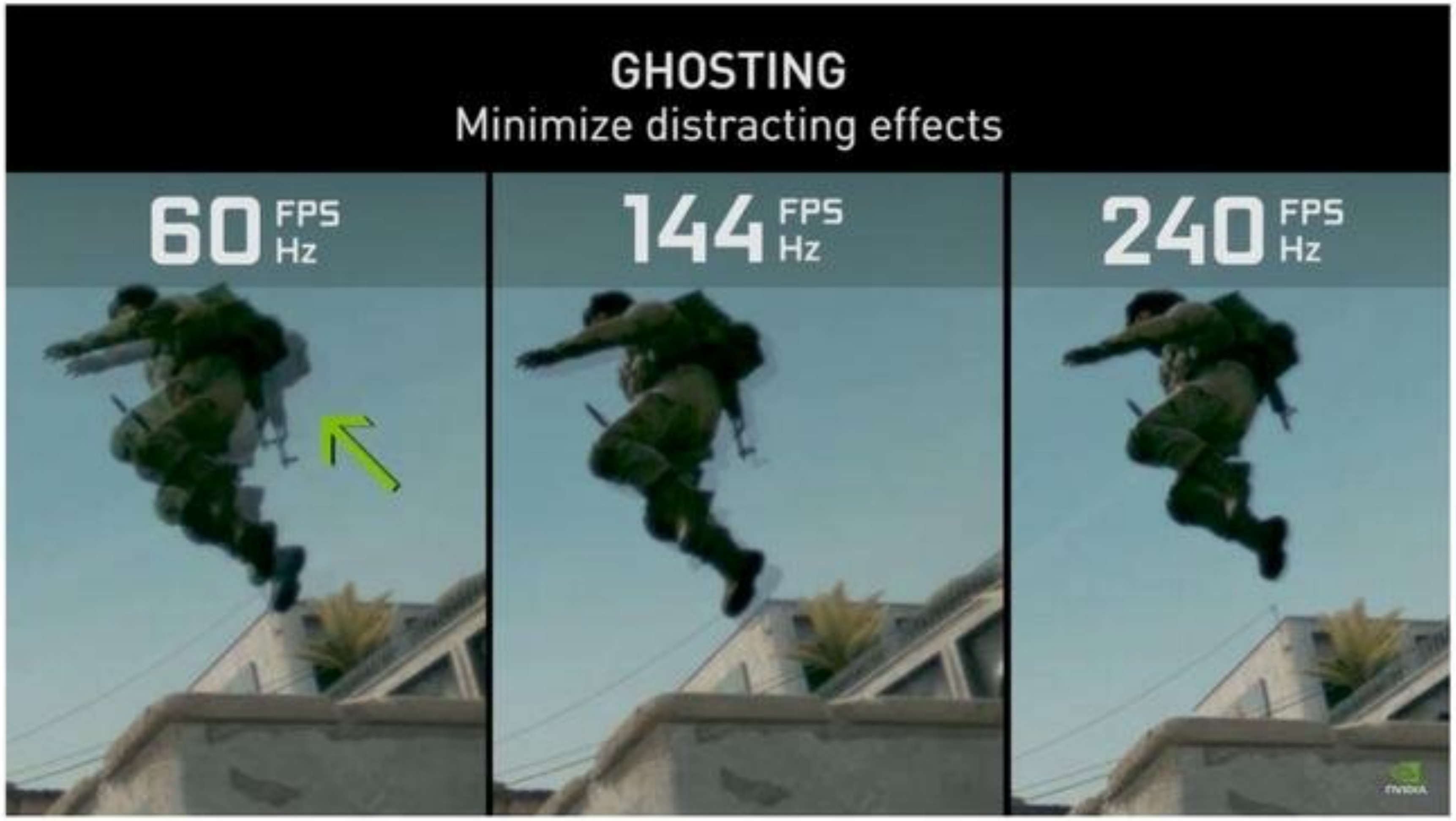
	Weights for Symptoms		
Symptoms	Nausea	Oculomotor	Disorientation
General discomfort	1	1	
Fatigue		1	
Headache		1	
Eye strain		1	
Difficulty focusing		1	1
Increased salivation	1		
Sweating	1		
Nausea	1		1
Difficulty concentrating	1	1	
Fullness of head			1
Blurred vision		1	1
Dizzy (eyes open)			1
Dizzy (eyes closed)			1
Vertigo			1
Stomach awareness	1		
Burping	1		
Total*	[1]	[2]	[3]

Fig. 5.2.1 Example of the symptoms and scores.(cybersickness.org)

FPS (Frame Per Second)



FPS (Frame Per Second)



FPS (Frame Per Second)

Safety-AR

Safety and Security Issues

Safety- VR

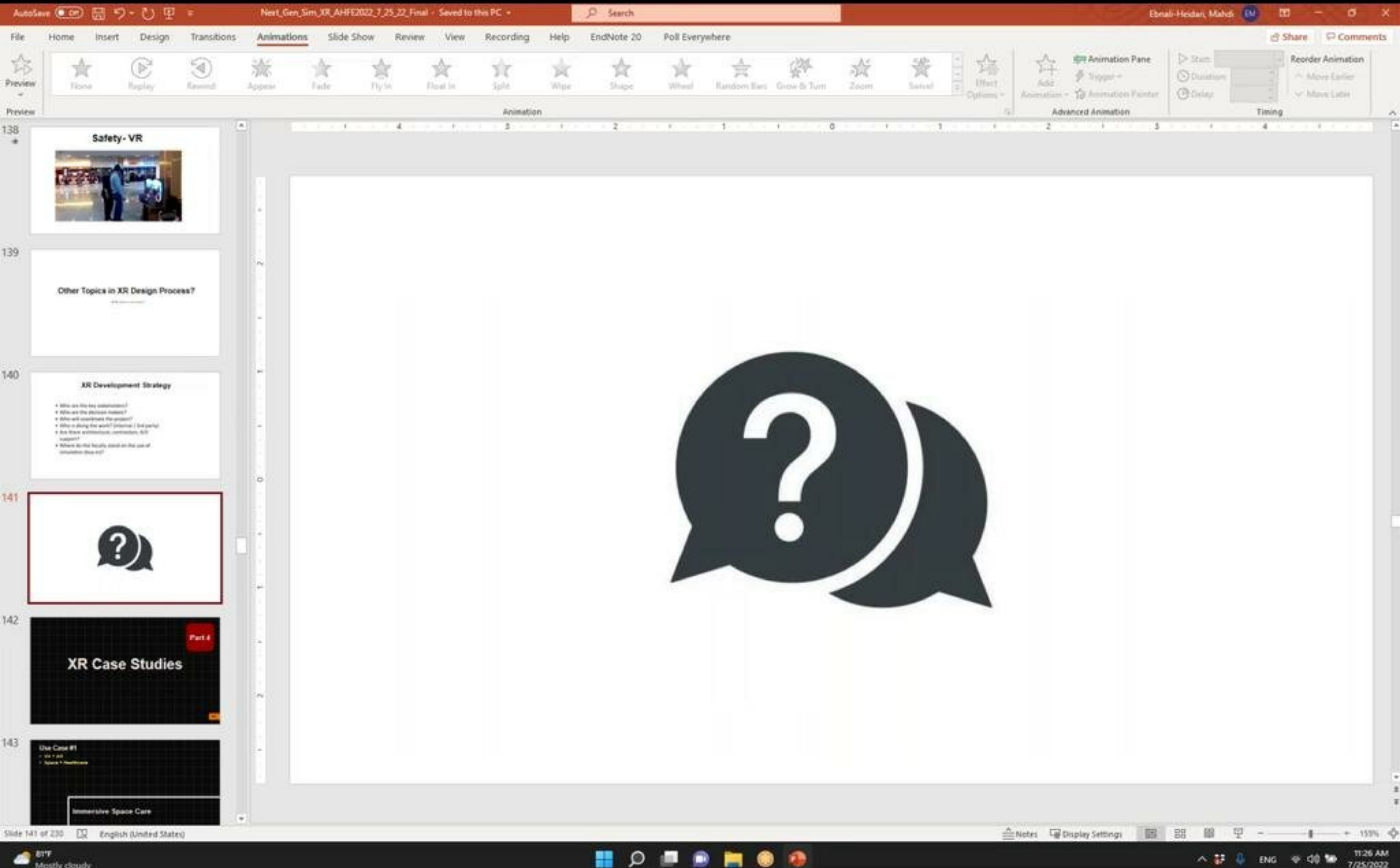
Safety- VR

XR Development Strategy

- Who are the key stakeholders?
- Who are the decision makers?
- Who will coordinate the project?
- Who is doing the work? (Internal / 3rd party)
- Are there architectural, contractors, A/V support?
- Where do the faculty stand on the use of simulation (buy-in)?

Other Topics in XR Design Process?

Well, there is too much!


AutoSave
Next_Gen_Sim_XR_AHFE2022_7_25_22_Final - Saved to this PC
Search
Ebnali-Heidari, Mahdi
File
Home
Insert
Design
Transitions
Animations
Slide Show
Review
View
Recording
Help
EndNote 20
Poll Everywhere
Share
Comments
Preview
Animation
Animation Pane
Advanced Animation
Timing
Reorder Animation
Safety- VR
Other Topics in XR Design Process?
XR Development Strategy
Part 4
XR Case Studies
Use Case #1
Immersive Space Care
Slide 141 of 230
English (United States)
Notes
Display Settings
81°F
Mostly cloudy
ENG
11:26 AM
7/25/2022

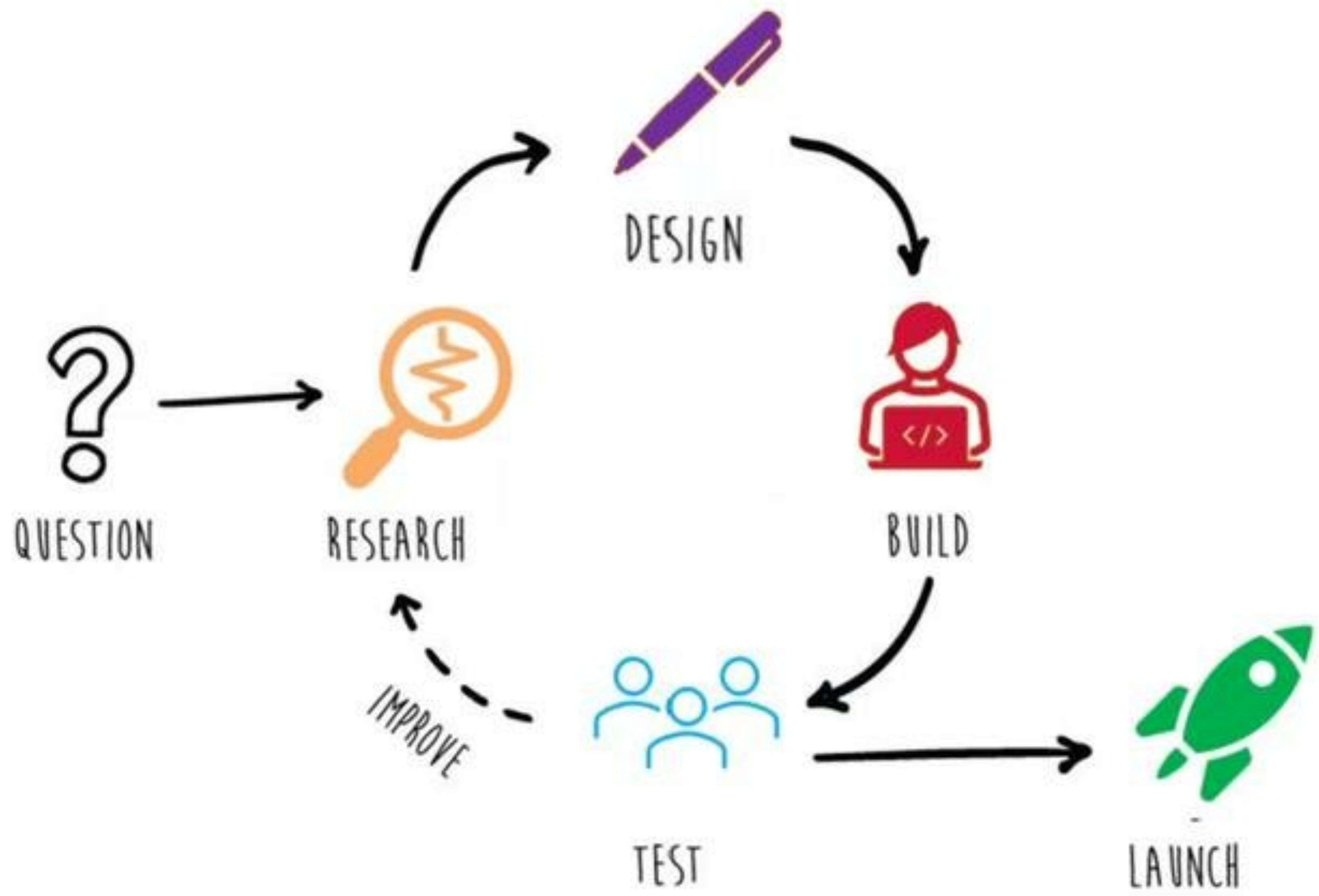
Use Case #1

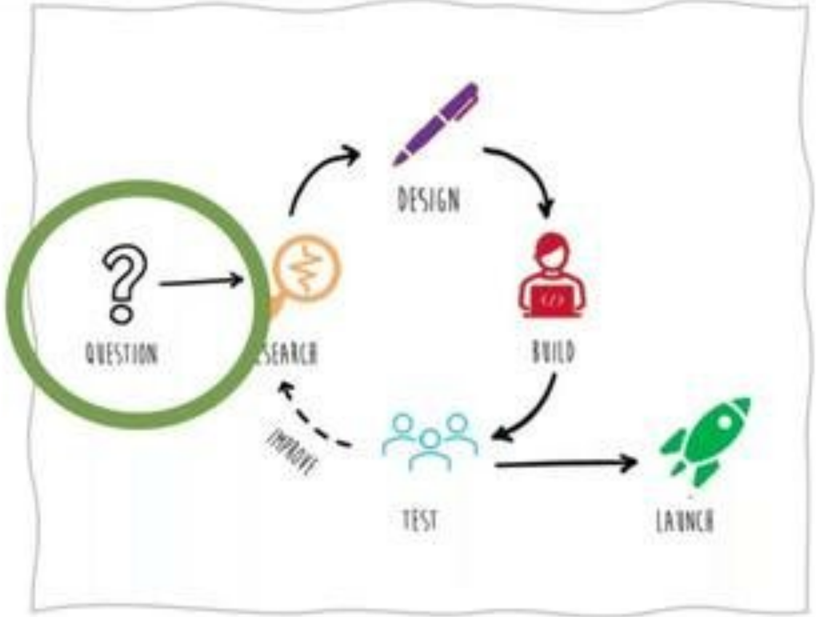
- VR + AR
- Space + Healthcare

Immersive Space Care

Part 4

XR Case Studies


DESIGN
QUESTION
RESEARCH
BUILD
IMPROVE
TEST
LAUNCH



- Usability of XR technology as in-flight training system and clinical guidance for space health during long-duration space missions

STRATUS
CENTER FOR MEDICAL SIMULATION

Human Factors &
Cognitive Engineering Lab

HARVARD
MEDICAL SCHOOL

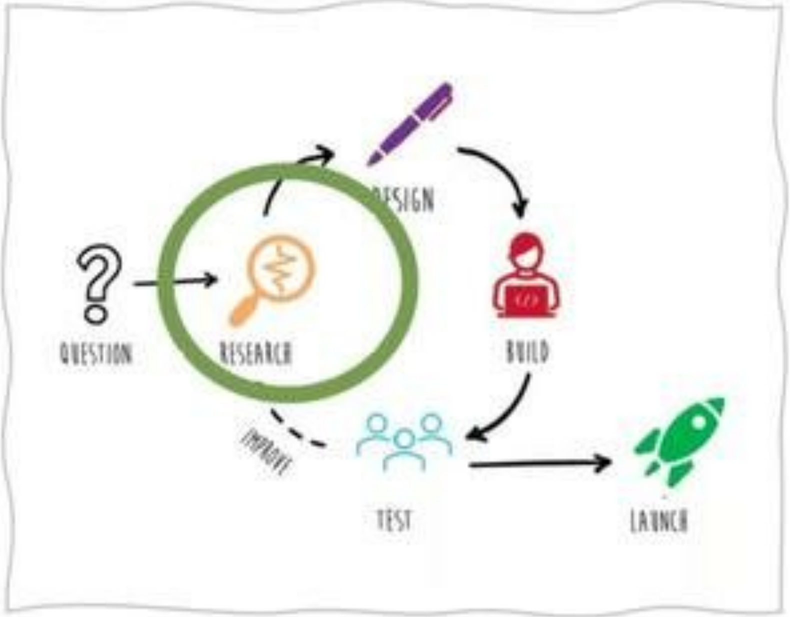
TRANSLATIONAL
RESEARCH INSTITUTE FOR
SPACE HEALTH

What to include?

How to design?

What are the functionalities?

What are the capabilities?

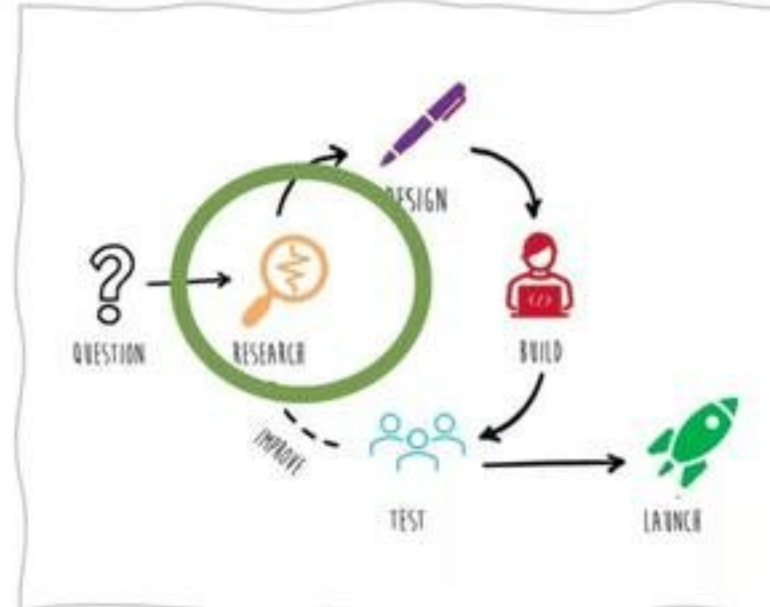


What to include?

How to design?

What are the functionalities?

What are the capabilities?

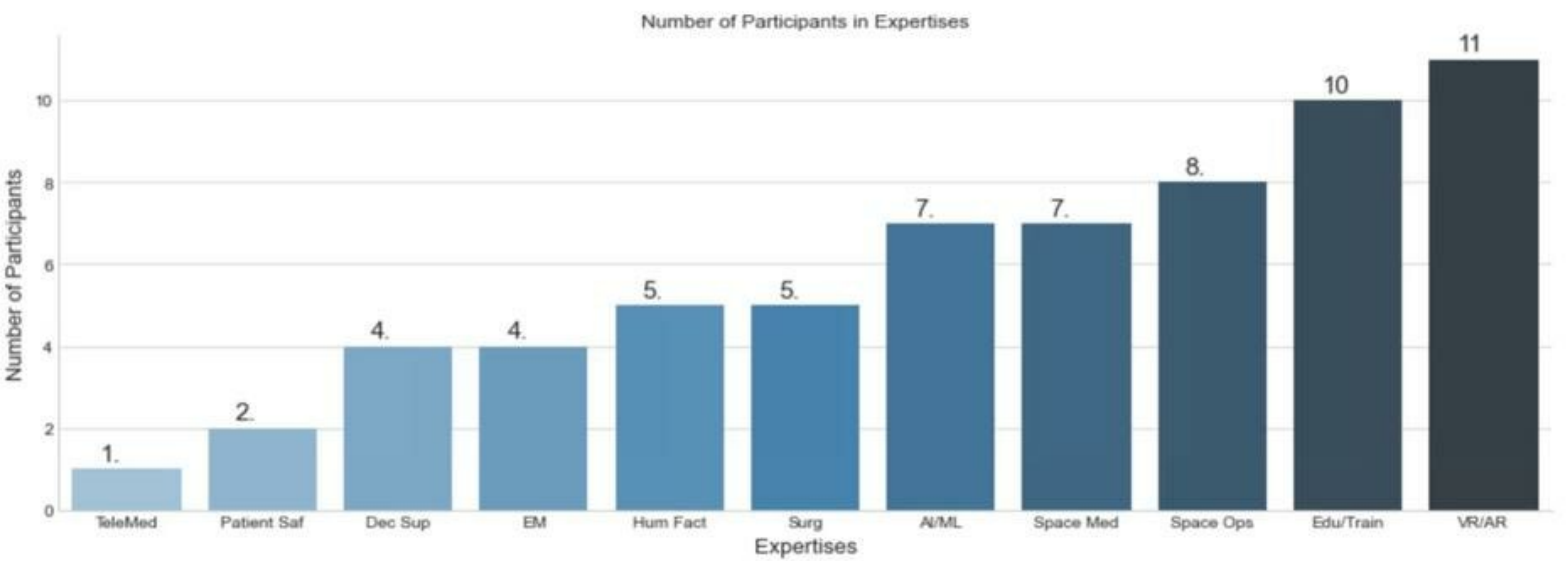


Experts Panel + Card Sorting

Essential capabilities of XR platforms for space applications were identified.

Expert Panels

Expert Panels



Number of Subject matter experts (SME) categorized based on expertise

Expert Panels

- 4 rounds of Delphi method

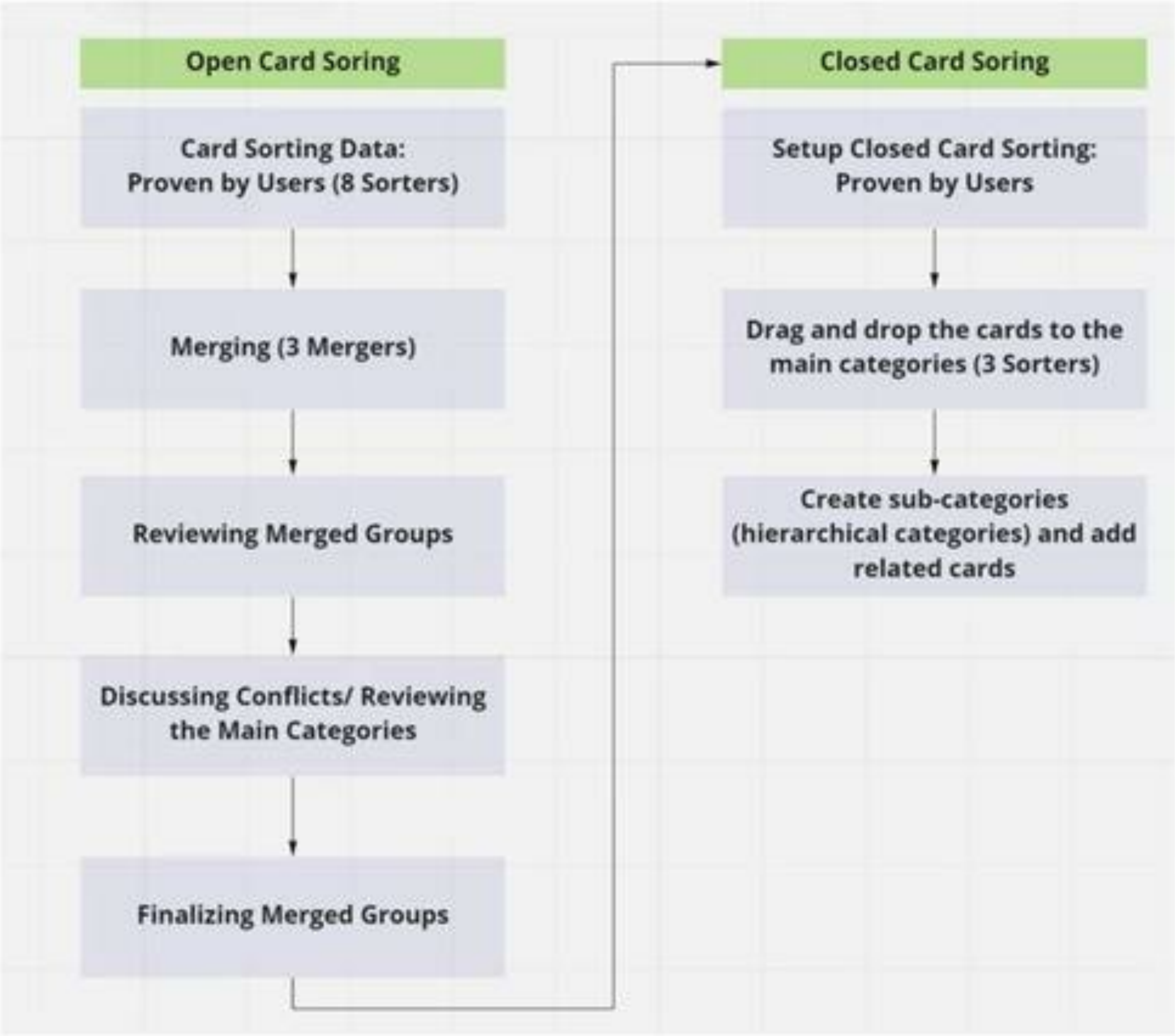
- To obtain SME consensus on which capabilities to be considered essential
- At the completion of the fourth Delphi survey, 76 capabilities were considered essential

Card Sorting

Card Sorting

PROVEN BY USERS

Card Sorting



Card Sorting

Card Sorting

Finally, 11 categories were identified and presented as an initial taxonomy of XR capabilities and technical features for medical training and clinical supports

Card Sorting

Finally, 11 categories were identified and presented as an initial taxonomy of XR capabilities and technical features for medical training and clinical supports

Category	Purpose
Extended Reality (XR)	Support inclusion of XR features (some specific to medicine)/ Permit multiple users within the XR environment
Assessment and Feedback	Structure performance feedback/ Provide feedback/ monitor progress Adapt to support individualized learning
Clinical Competence	Gain new or refresh existing knowledge/ Train procedural, technical and non-technical skills
Clinical Guidance	Provide clinical guidance
Environmental Fidelity	Have environmental realism
Interoperability and Integration	Integrate multiple sources and kinds of data/information/ Integrate with other systems on- and off-board
Machine Learning/ Artificial Intelligence	Use artificial intelligence
Platform Customization	Enable customization of the XR platform
Adaptive Learning	Adapt to support individualized learning
Training Modalities/ Pedagogy	Structure and enable approaches to experiential learning
User Experience and Interface	Optimize usability and clinical applicability

Cognitive Task Analysis (CTA)

Cognitive Task Analysis (CTA)

- 5 experts (3 clinicians, 2 human factors researchers, and 1 XR developer)
- To elucidate the process model of a scenario (specific scenario) to diagnose a potentially life-threatening condition

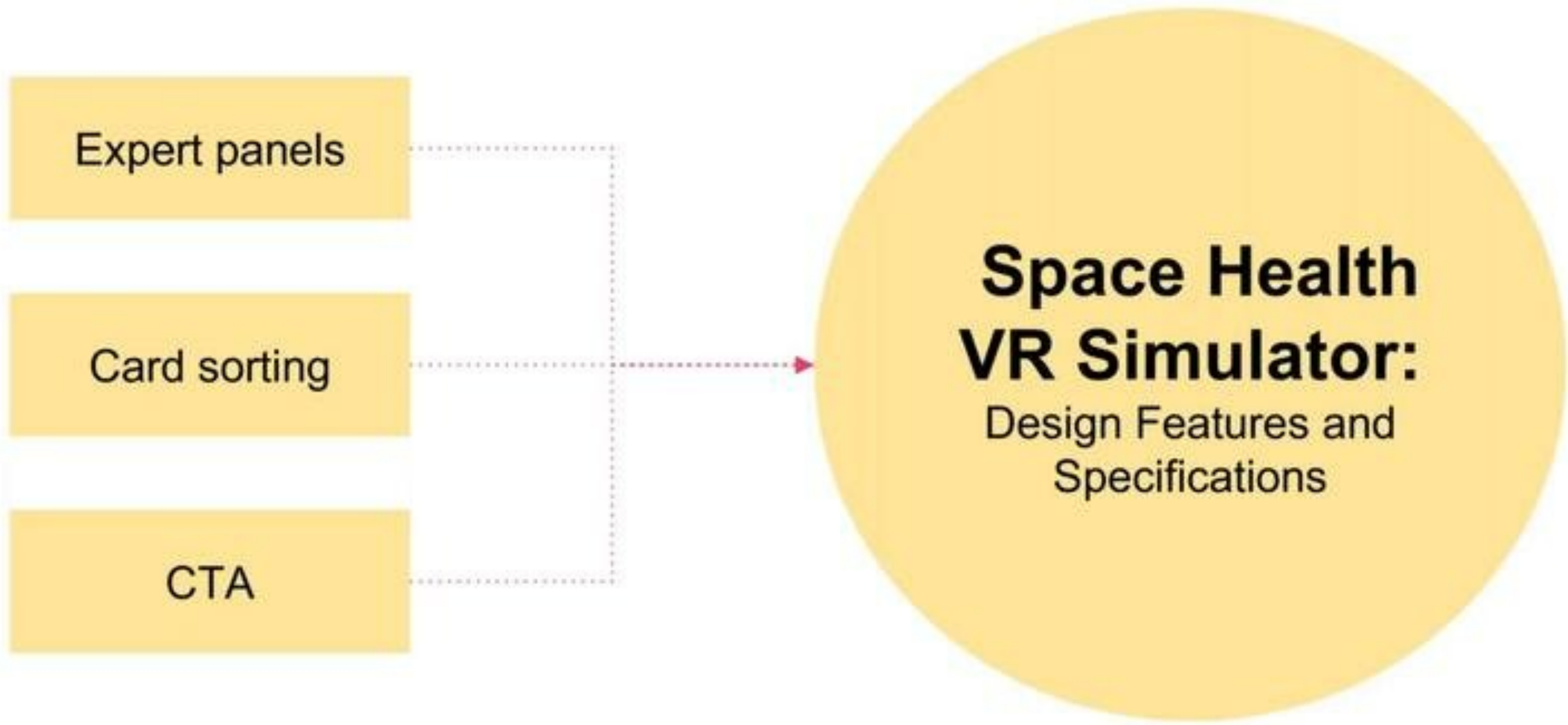
Specifying Design Features

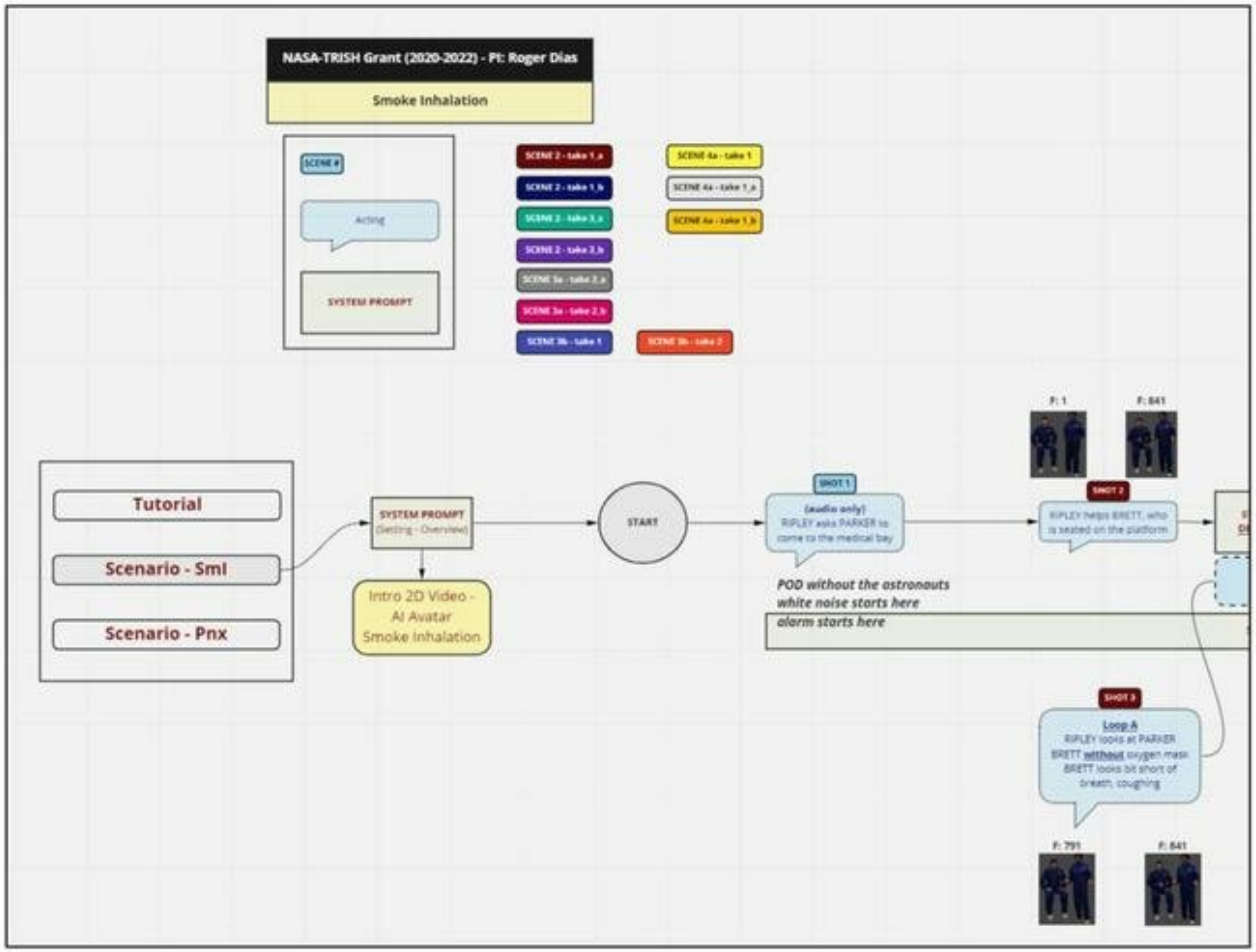
Expert panels

Card sorting

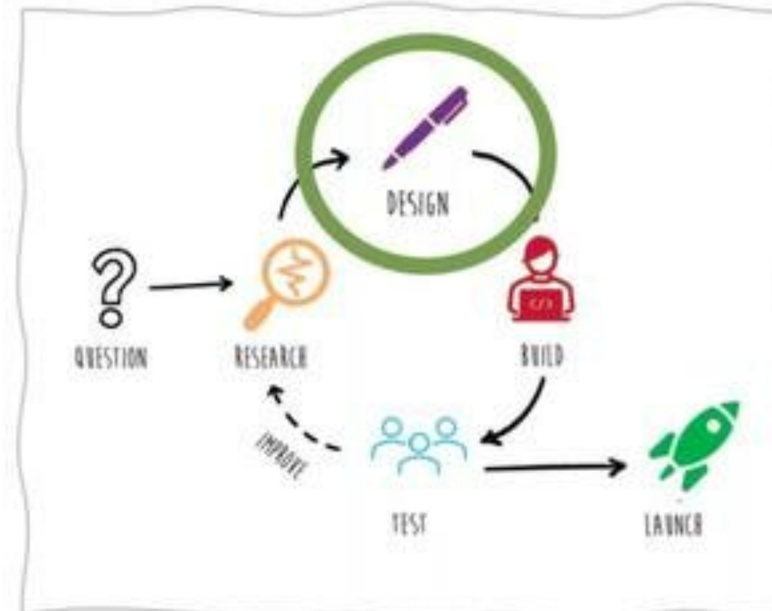
CTA

Specifying Design Features



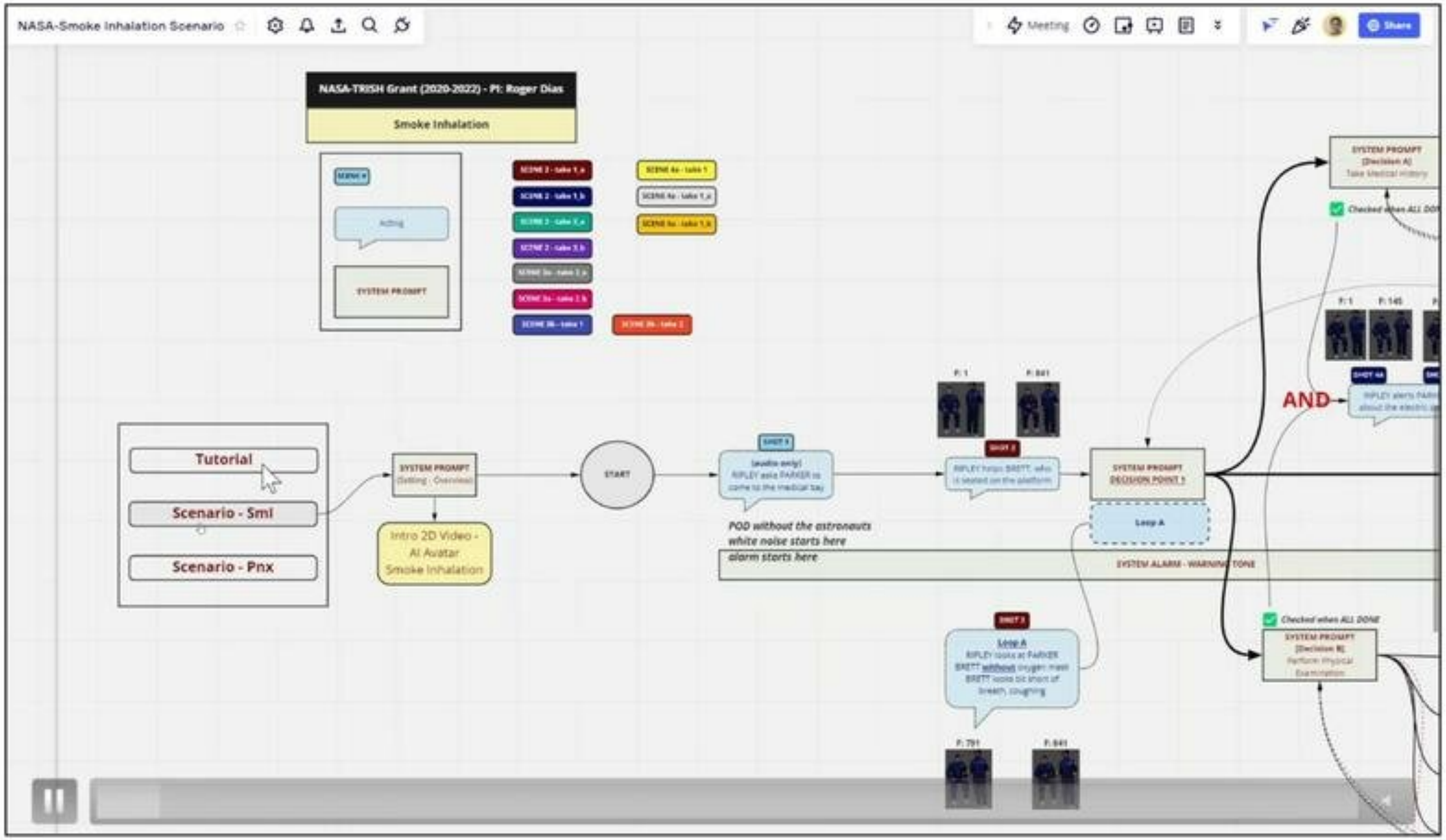


NASA-TRISH Grant (2020-2022) - PI: Roger Dias
Smoke Inhalation
SCENE #
Acting
SYSTEM PROMPT
SCENE 2 - take 1_a
SCENE 2 - take 1_b
SCENE 2 - take 3_a
SCENE 2 - take 3_b
SCENE 3a - take 2_a
SCENE 3a - take 2_b
SCENE 3b - take 1
SCENE 3b - take 2
SCENE 4a - take 1
SCENE 4a - take 1_a
SCENE 4a - take 1_b
Tutorial
Scenario - Sml
Scenario - Pnx
SYSTEM PROMPT
(Setting - Overview)
Intro 2D Video -
AI Avatar
Smoke Inhalation
START
SHOT 1
(audio only)
RIPLEY asks PARKER to come to the medical bay
POD without the astronauts
white noise starts here
alarm starts here
F: 1
F: 841
SHOT 2
RIPLEY helps BRETT, who is seated on the platform
SHOT 3
Loop A
RIPLEY looks at PARKER
BRETT without oxygen mask
BRETT looks bit short of breath, coughing
F: 791
F: 841

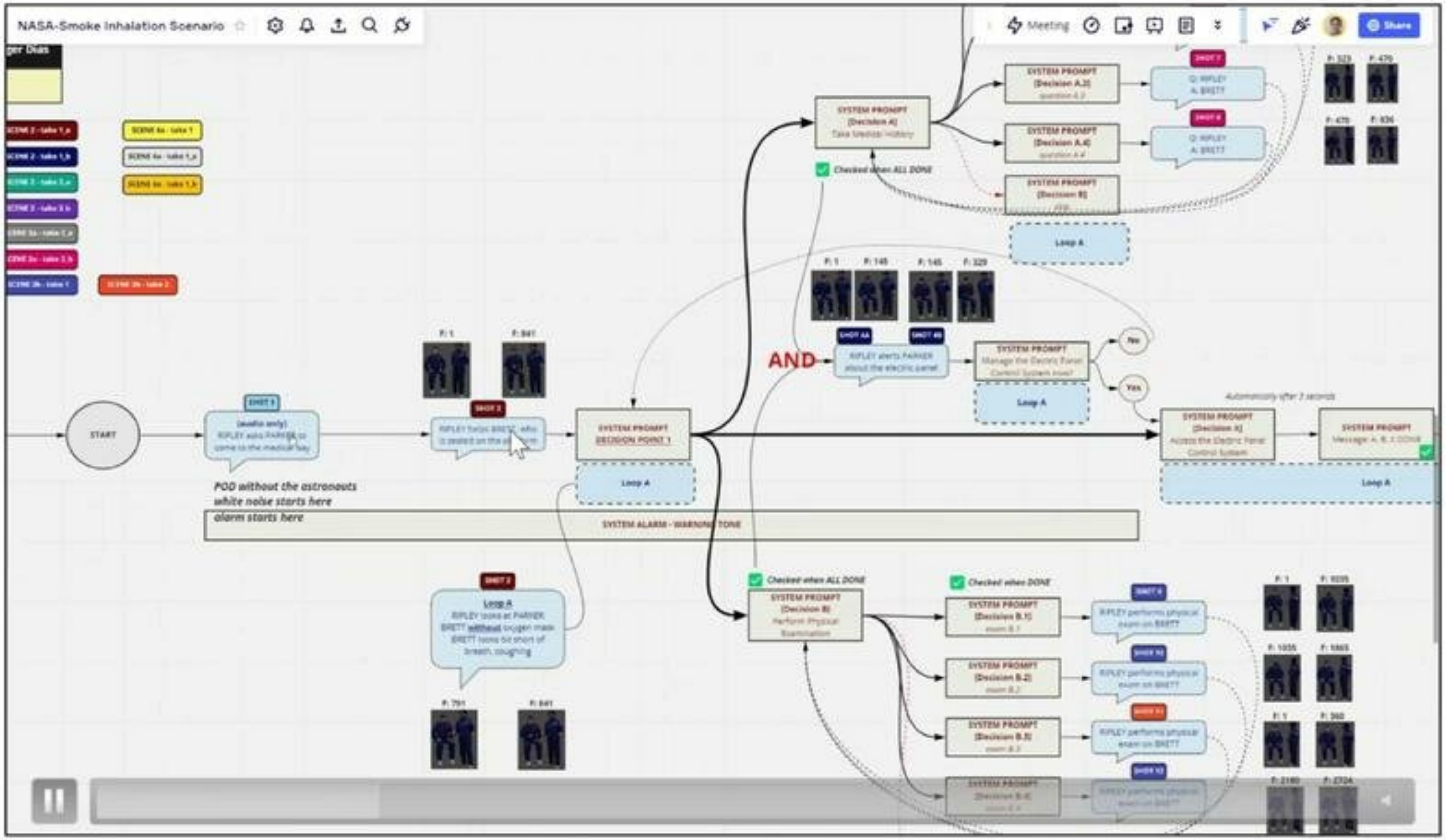


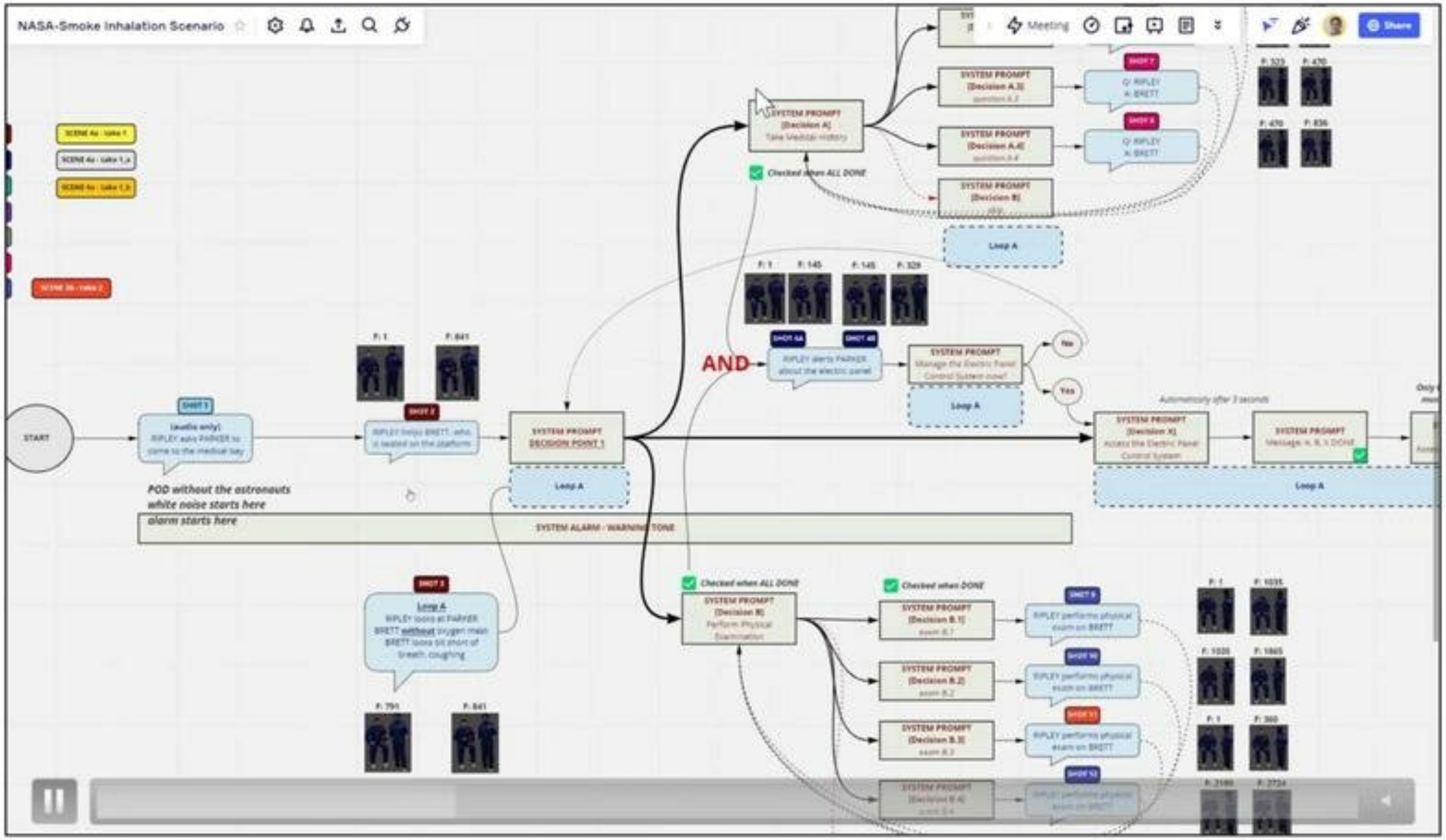
QUESTION
RESEARCH
DESIGN
BUILD
TEST
LAUNCH
IMPROVE

SCENARIO
GUI

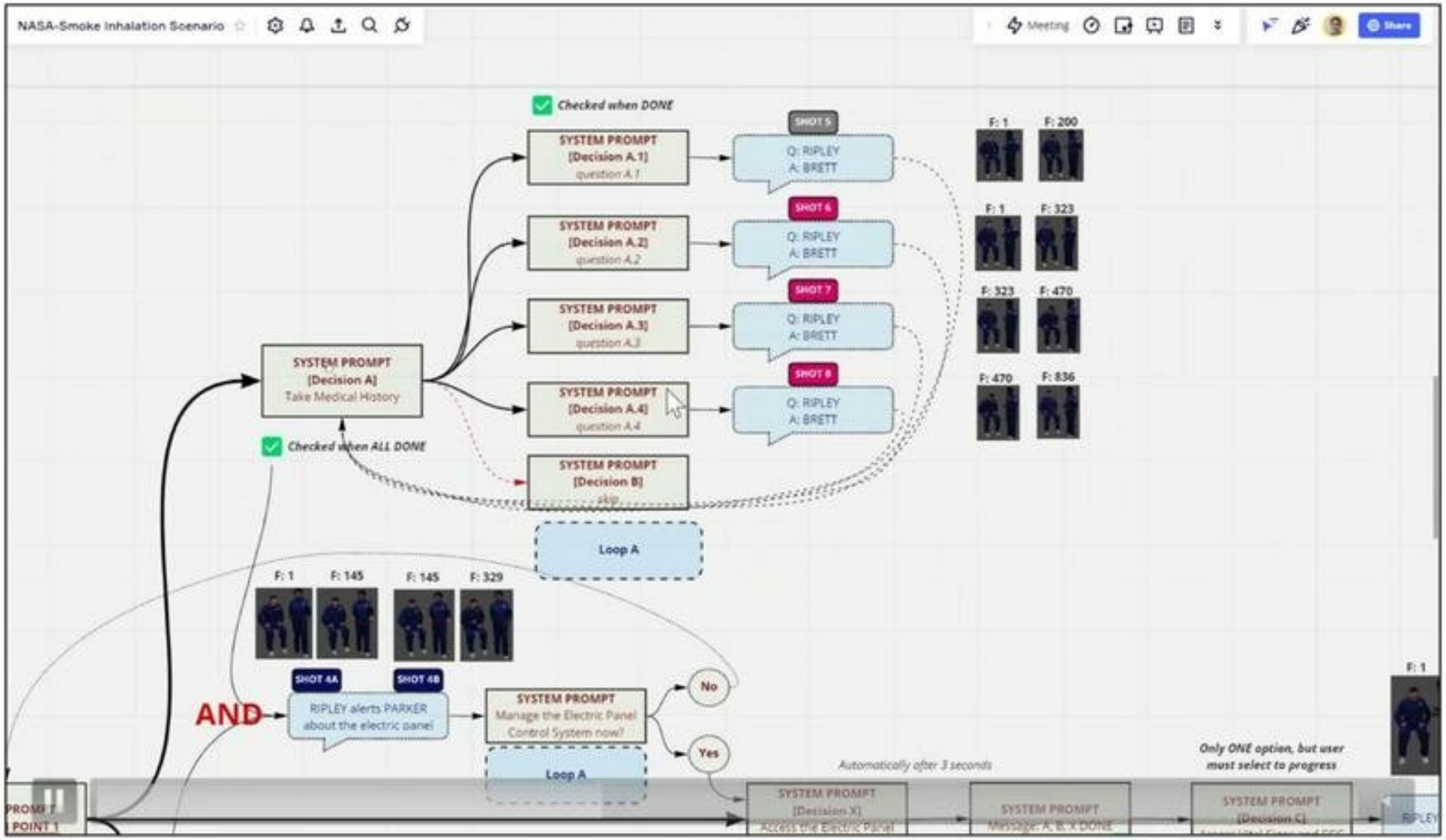


NASA-Smoke Inhalation Scenario
Meeting
Share
NASA-TRISH Grant (2020-2022) - PI: Roger Dias
Smoke Inhalation
Tutorial
Scenario - Sml
Scenario - Pnx
SYSTEM PROMPT
START
Intro 2D Video - AI Avatar Smoke Inhalation
POD without the astronauts
white noise starts here
alarm starts here
AND
SYSTEM ALARM - WARNING TONE
Loop A
Checked when ALL DONE

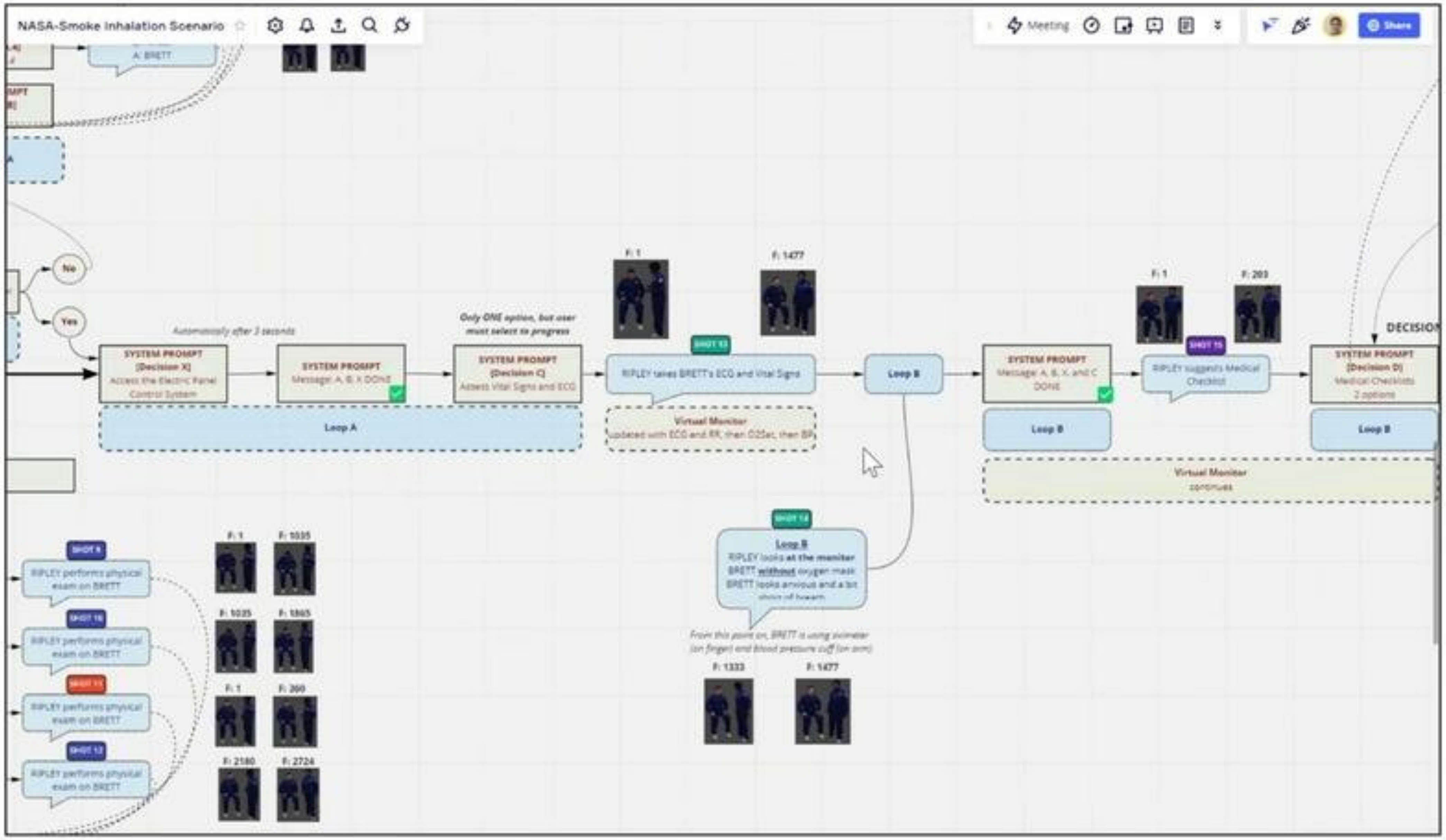

NASA-Smoke Inhalation Scenario
Meeting
Share
START
AND
POD without the astronauts
white noise starts here
alarm starts here
SYSTEM ALARM - WARNING TONE
Checked when ALL DONE
Checked when DONE
Automatically after 3 seconds
Loop A

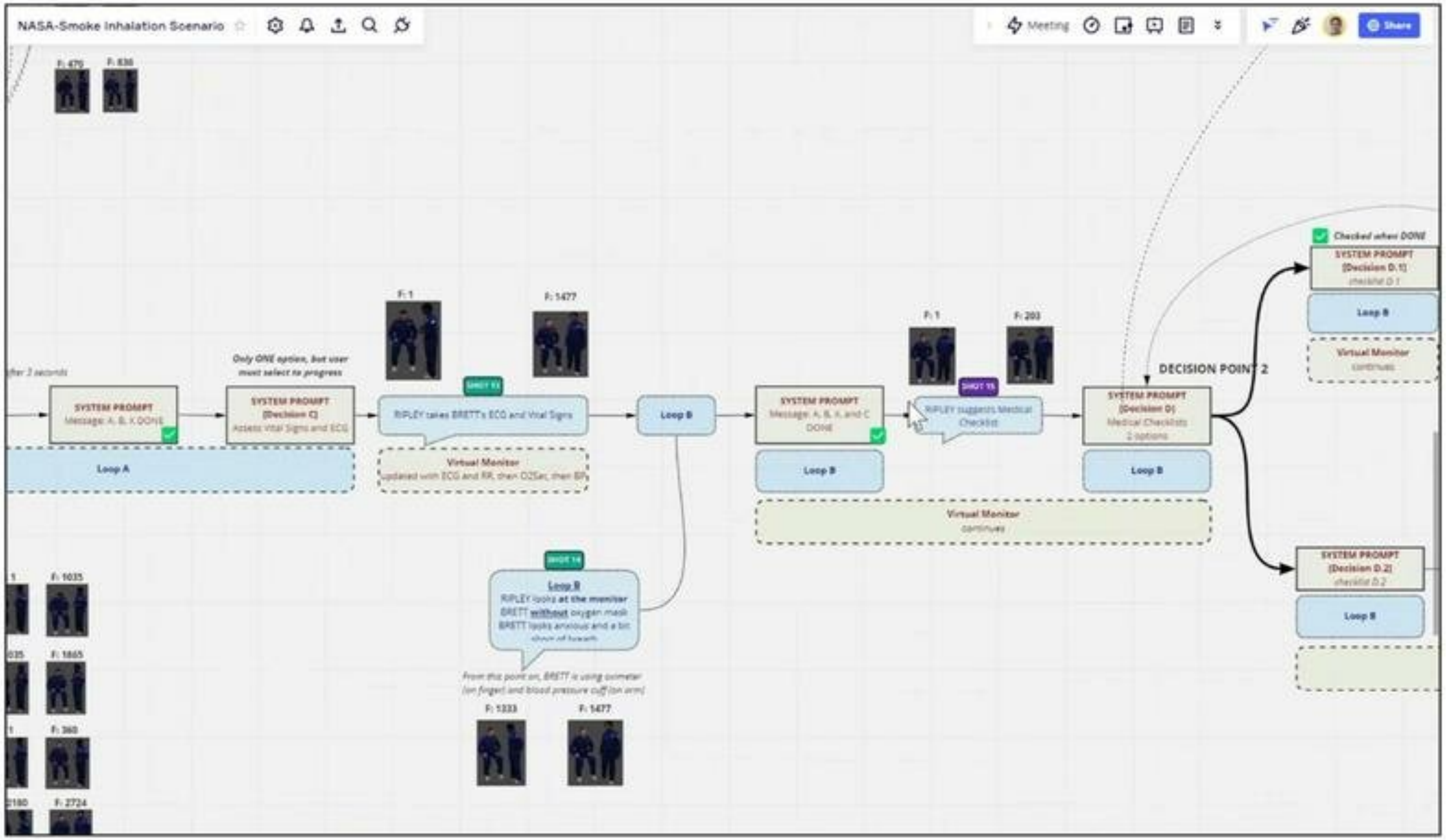


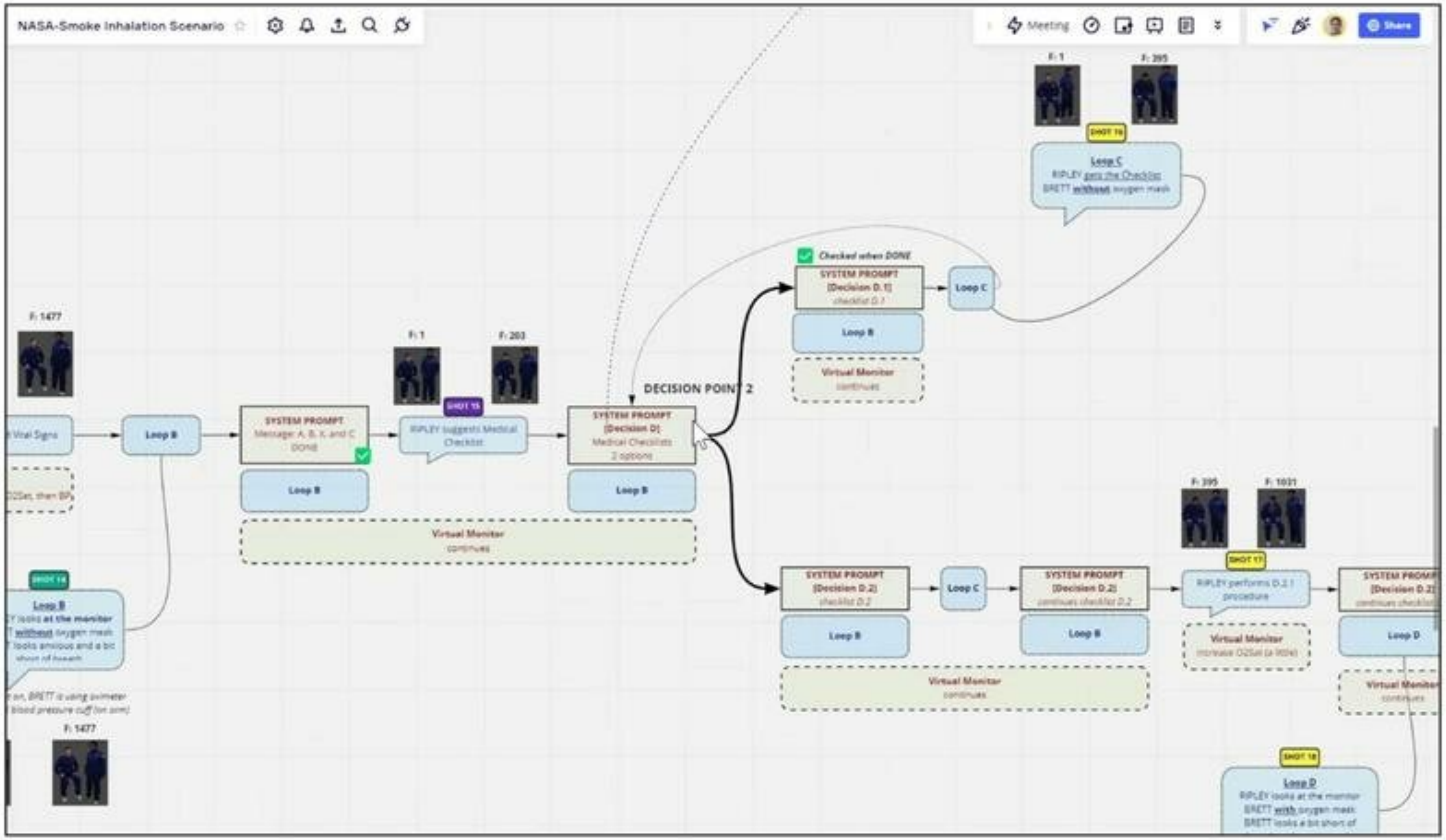
NASA-Smoke Inhalation Scenario
Meeting
Share
START
POD without the astronauts
white noise starts here
alarm starts here
SYSTEM ALARM - WARNING TONE
SYSTEM PROMPT
DECISION POINT 1
Loop A
AND
Checked when ALL DONE
Checked when DONE

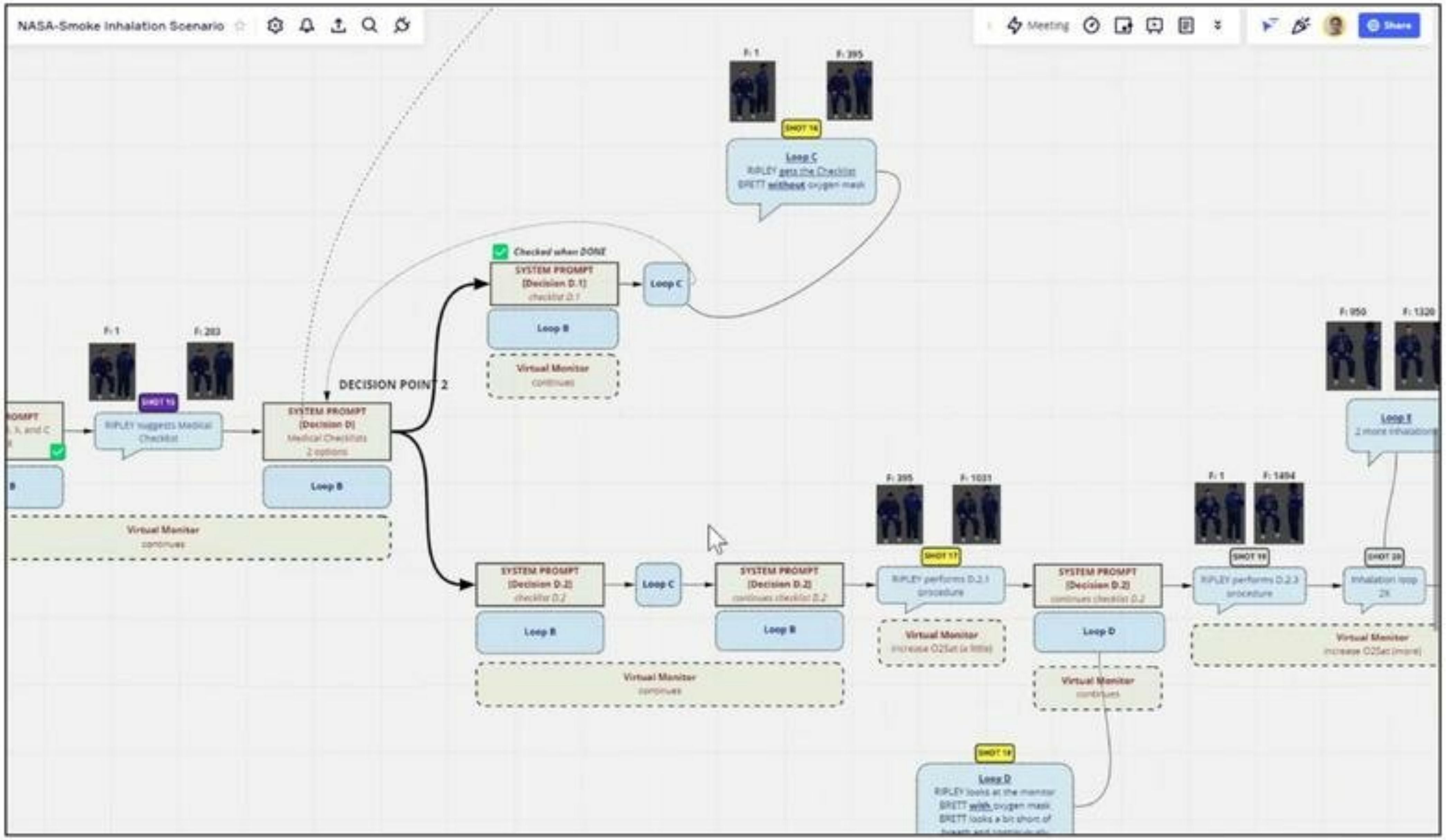


NASA-Smoke Inhalation Scenario
Checked when DONE
SYSTEM PROMPT [Decision A.1] question A.1
SYSTEM PROMPT [Decision A.2] question A.2
SYSTEM PROMPT [Decision A.3] question A.3
SYSTEM PROMPT [Decision A.4] question A.4
SYSTEM PROMPT [Decision B] skip
SHOT 5
SHOT 6
SHOT 7
SHOT 8
Q: RIPLEY A: BRETT
SYSTEM PROMPT [Decision A] Take Medical History
Checked when ALL DONE
Loop A
AND
SHOT 4A
SHOT 4B
RIPLEY alerts PARKER about the electric panel
SYSTEM PROMPT Manage the Electric Panel Control System now?
No
Yes
Automatically after 3 seconds
Only ONE option, but user must select to progress
SYSTEM PROMPT [Decision X] Access the Electric Panel
SYSTEM PROMPT Message: A, B, X DONE
SYSTEM PROMPT [Decision C]

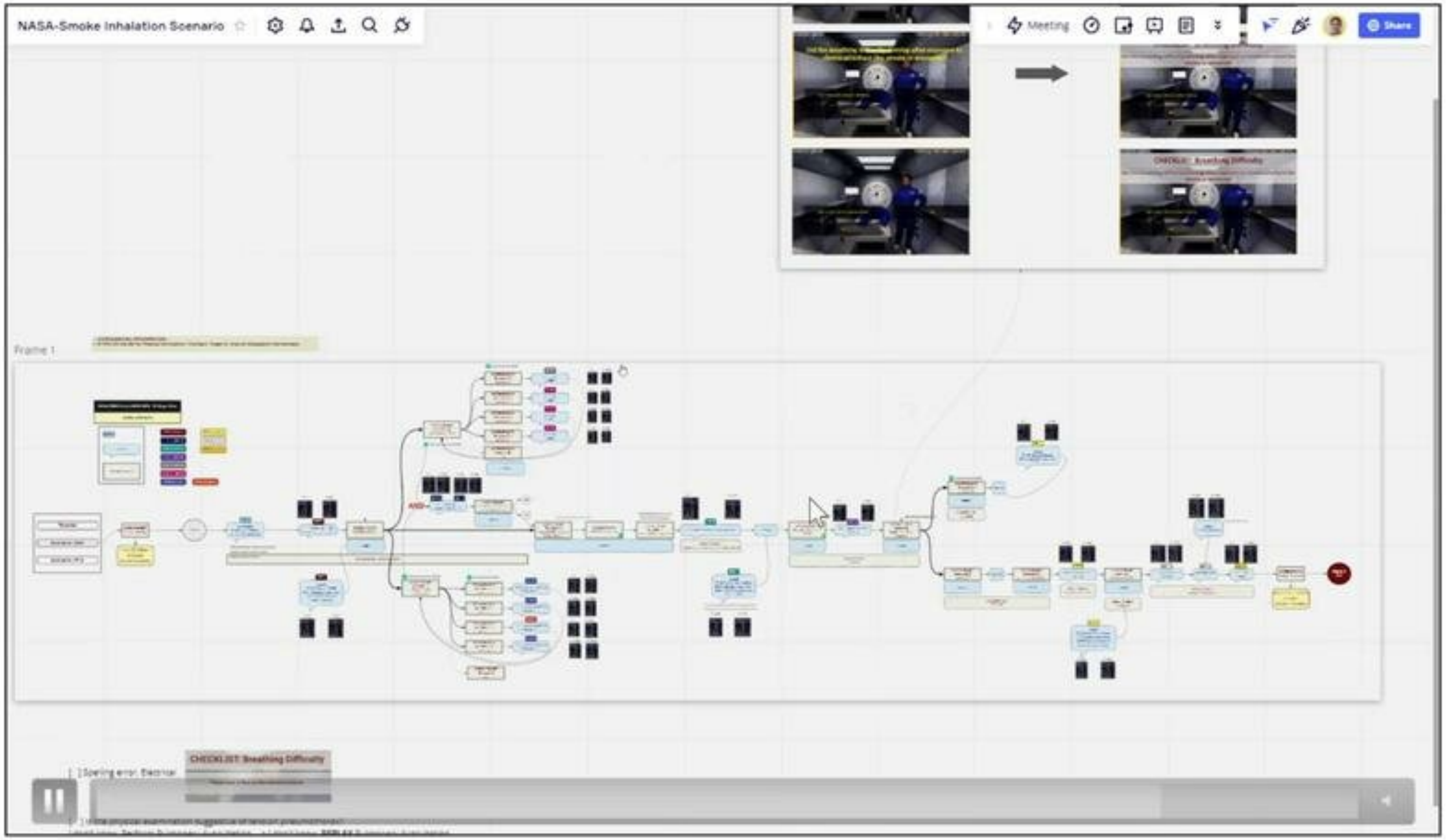

NASA-Smoke Inhalation Scenario
Meeting
Share
No
Yes
Automatically after 3 seconds
SYSTEM PROMPT
(Decision X)
Access the Electric Panel Control System
SYSTEM PROMPT
Message: A, B, X DONE
Only ONE option, but user must select to progress
SYSTEM PROMPT
(Decision C)
Assess Vital Signs and ECG
Loop A
F: 1
F: 1477
RIPLEY takes BRETT's ECG and Vital Signs
Virtual Monitor
updated with ECG and RR, then O2Sat, then BP
Loop B
SYSTEM PROMPT
Message: A, B, X, and C DONE
Loop B
F: 1
F: 203
SHOT 15
RIPLEY suggests Medical Checklist
DECISION
SYSTEM PROMPT
(Decision D)
Medical Checklists
2 options
Loop B
Virtual Monitor
continues
Loop B
RIPLEY looks at the monitor
BRETT without oxygen mask
BRETT looks anxious and a bit short of breath
From this point on, BRETT is using oximeter (on finger) and blood pressure cuff (on arm)
F: 1333
F: 1477
RIPLEY performs physical exam on BRETT
RIPLEY performs physical exam on BRETT
RIPLEY performs physical exam on BRETT
RIPLEY performs physical exam on BRETT
F: 1
F: 1035
F: 1035
F: 1865
F: 1
F: 360
F: 2180
F: 2724

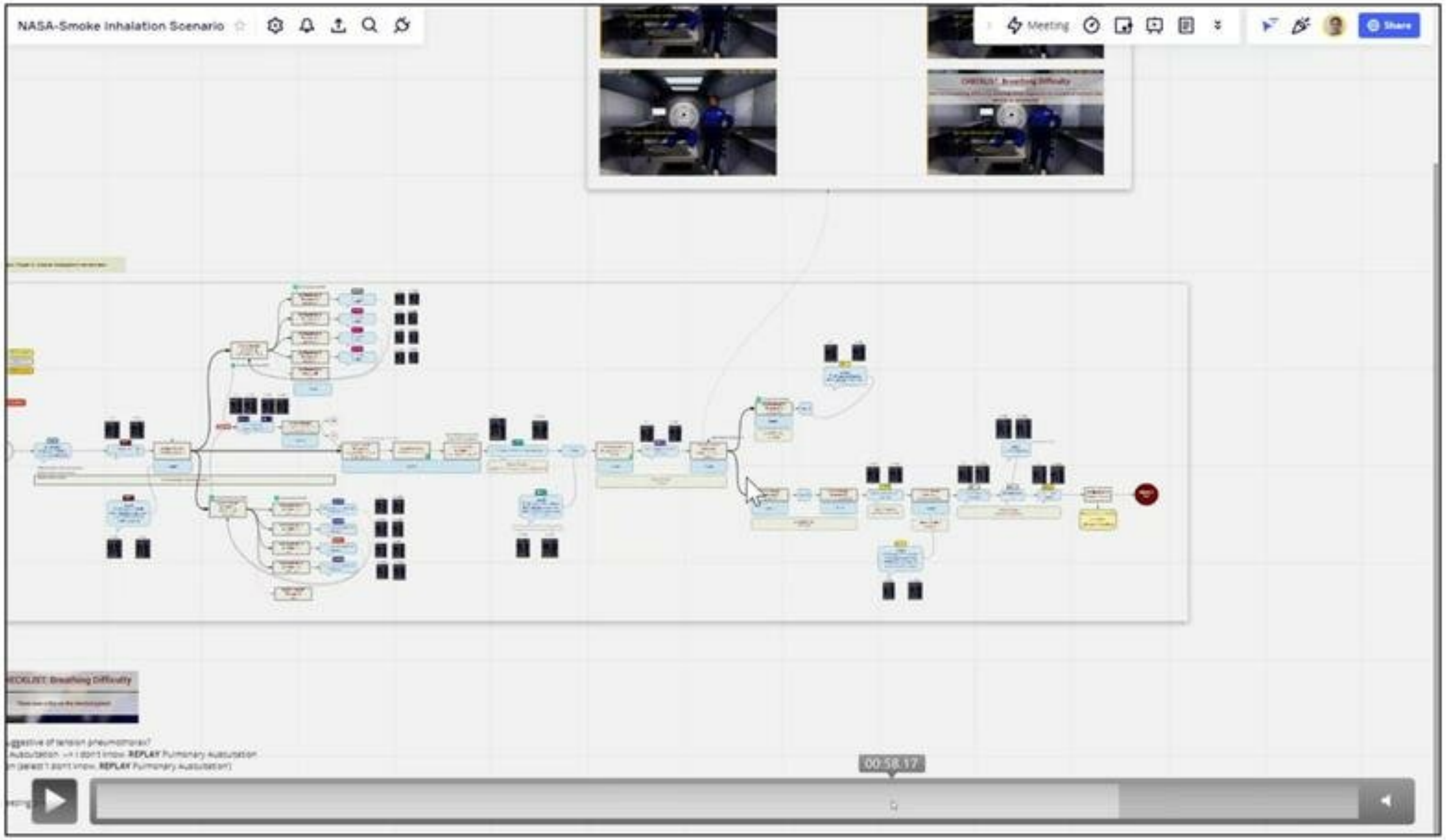

NASA-Smoke Inhalation Scenario
Meeting
Share
Only ONE option, but user must select to progress
SYSTEM PROMPT
SYSTEM PROMPT
(Decision C)
RIPLEY takes BRETT's ECG and Vital Signs
Loop A
Virtual Monitor
Loop B
Loop B
RIPLEY looks at the monitor
BRETT without oxygen mask
From this point on, BRETT is using oximeter (on finger) and blood pressure cuff (on arm)
SYSTEM PROMPT
Loop B
Virtual Monitor
continues
DECISION POINT 2
SYSTEM PROMPT
(Decision D)
Medical Checklists
Loop B
Checked when DONE
SYSTEM PROMPT
(Decision D.1)
Loop B
Virtual Monitor
continues
SYSTEM PROMPT
(Decision D.2)
Loop B

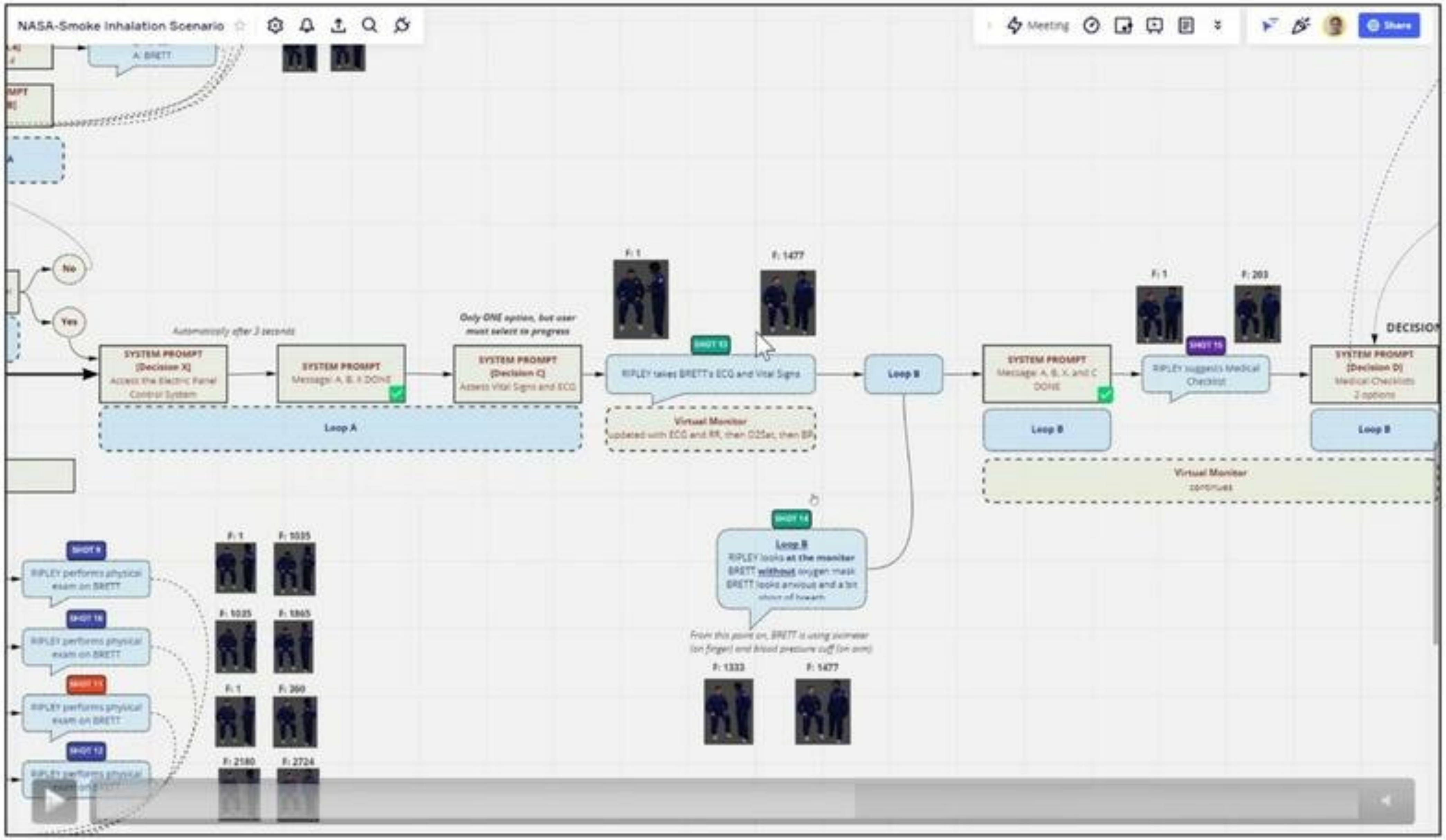

NASA-Smoke Inhalation Scenario
Meeting
Share
F: 1
F: 395
SHOT 16
Loop C
RIPLEY gets the Checklist
BRETT without oxygen mask
Checked when DONE
SYSTEM PROMPT
[Decision D.1]
checklist D.1
Loop C
Loop B
Virtual Monitor
continues
F: 1477
F: 1
F: 203
DECISION POINT 2
SHOT 15
Loop B
SYSTEM PROMPT
Message A, B, X and C
DONE
RIPLEY suggests Medical Checklist
SYSTEM PROMPT
[Decision D]
Medical Checklists
2 options
Loop B
Loop B
Virtual Monitor
continues
F: 395
F: 1031
SHOT 17
SYSTEM PROMPT
[Decision D.2]
checklist D.2
Loop C
SYSTEM PROMPT
[Decision D.2]
continues checklist D.2
RIPLEY performs D.2.1 procedure
Loop B
Loop B
Virtual Monitor
continues
Virtual Monitor
Loop D
SHOT 14
Loop B
without oxygen mask
F: 1477
SHOT 18
Loop D
RIPLEY looks at the monitor
BRETT with oxygen mask
BRETT looks a bit short of



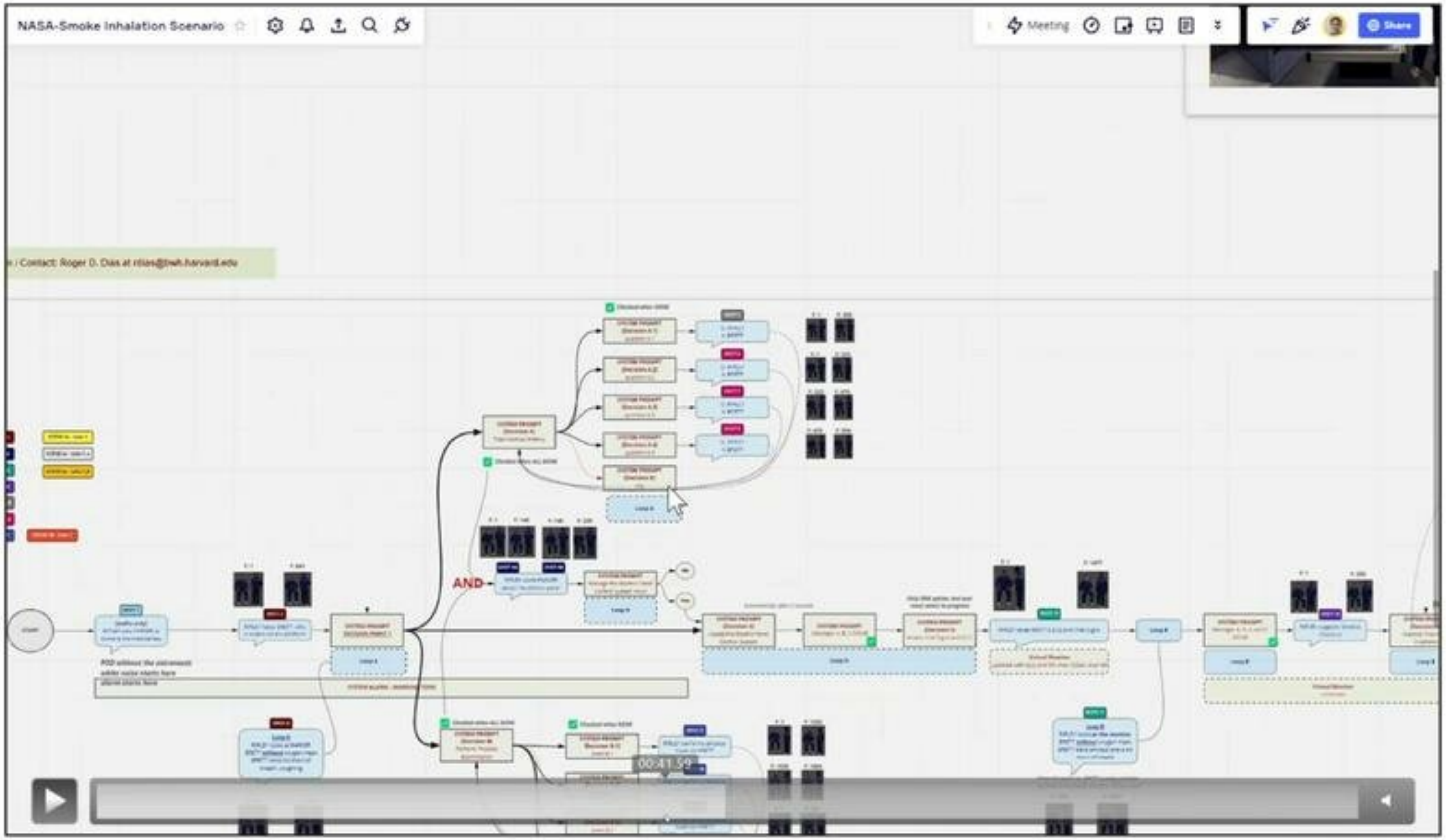
NASA-Smoke Inhalation Scenario
Meeting
Share
F: 1
F: 395
SHOT 16
Loop C
RIPLEY gets the Checklist
BRETT without oxygen mask
Checked when DONE
SYSTEM PROMPT
(Decision D.1)
checklist D.1
Loop C
Loop B
Virtual Monitor
continues
F: 1
F: 203
SHOT 15
RIPLEY suggests Medical Checklist
DECISION POINT 2
SYSTEM PROMPT
(Decision D)
Medical Checklists
2 options
Loop B
Virtual Monitor
continues
SYSTEM PROMPT
(Decision D.2)
checklist D.2
Loop C
Loop B
SYSTEM PROMPT
(Decision D.2)
continues checklist D.2
Loop B
Virtual Monitor
continues
F: 395
F: 1031
SHOT 17
RIPLEY performs D.2.1 procedure
Virtual Monitor
increase O2Sat (a little)
SYSTEM PROMPT
(Decision D.2)
continues checklist D.2
Loop D
Virtual Monitor
continues
SHOT 18
Loop D
RIPLEY looks at the monitor
BRETT with oxygen mask
BRETT looks a bit short of
F: 1
F: 1494
SHOT 19
RIPLEY performs D.2.3 procedure
SHOT 20
Inhalation loop 2X
Virtual Monitor
increase O2Sat (more)
F: 950
F: 1320
Loop E
2 more inhalations


NASA-Smoke Inhalation Scenario
Meeting
Share
Frame 1
CHECKLIST: Breathing Difficulty


NASA-Smoke Inhalation Scenario
Meeting
Share
00:58:17

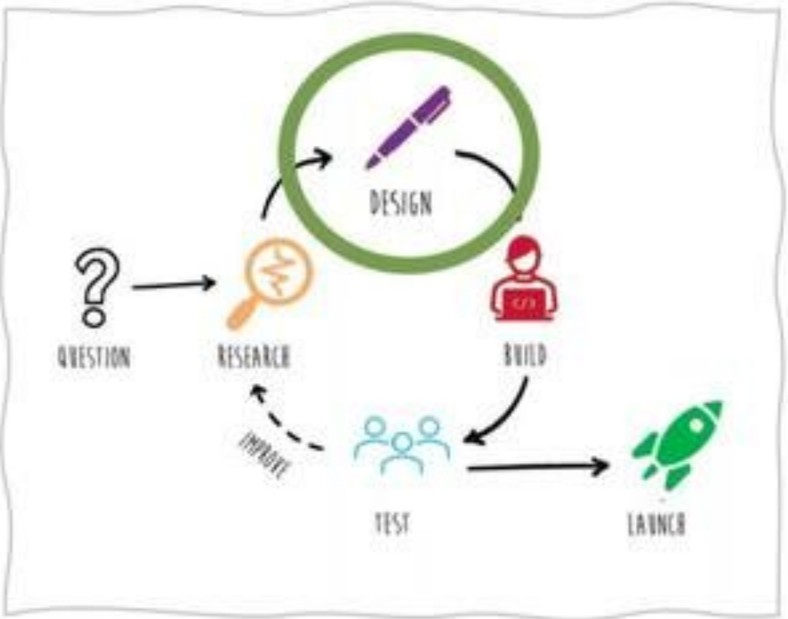


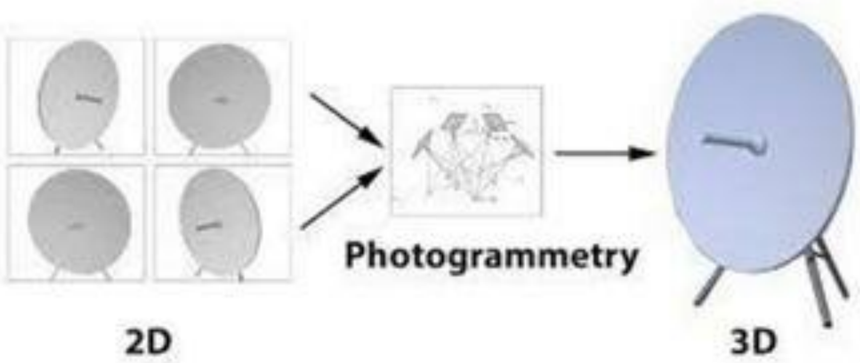
NASA-Smoke Inhalation Scenario
Meeting
Share
No
Yes
Automatically after 3 seconds
SYSTEM PROMPT [Decision X]
SYSTEM PROMPT
Only ONE option, but user must select to progress
SYSTEM PROMPT [Decision C]
F: 1
F: 1477
RIPLEY takes BRETT's ECG and Vital Signs
Loop A
Virtual Monitor updated with ECG and RR, then O2Sat, then BP
Loop B
SYSTEM PROMPT
F: 1
F: 203
RIPLEY suggests Medical Checklist
DECISION
SYSTEM PROMPT [Decision D]
Loop B
Loop B
Virtual Monitor continues
RIPLEY performs physical exam on BRETT
RIPLEY performs physical exam on BRETT
RIPLEY performs physical exam on BRETT
F: 1
F: 1035
F: 1035
F: 1865
F: 1
F: 360
F: 2180
F: 2724
Loop B
RIPLEY looks at the monitor BRETT without oxygen mask BRETT looks anxious and a bit short of breath
From this point on, BRETT is using oximeter (on finger) and blood pressure cuff (on arm)
F: 1333
F: 1477

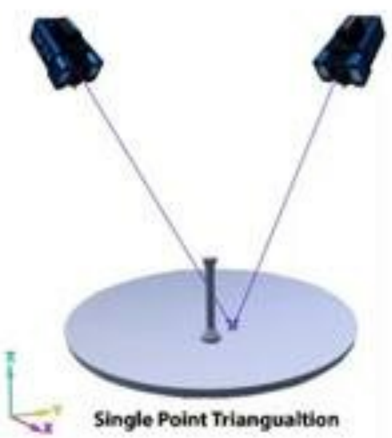

NASA-Smoke Inhalation Scenario
Meeting
Share
/ Contact: Roger D. Dias at rdias@bwh.harvard.edu
AND
00:41:59

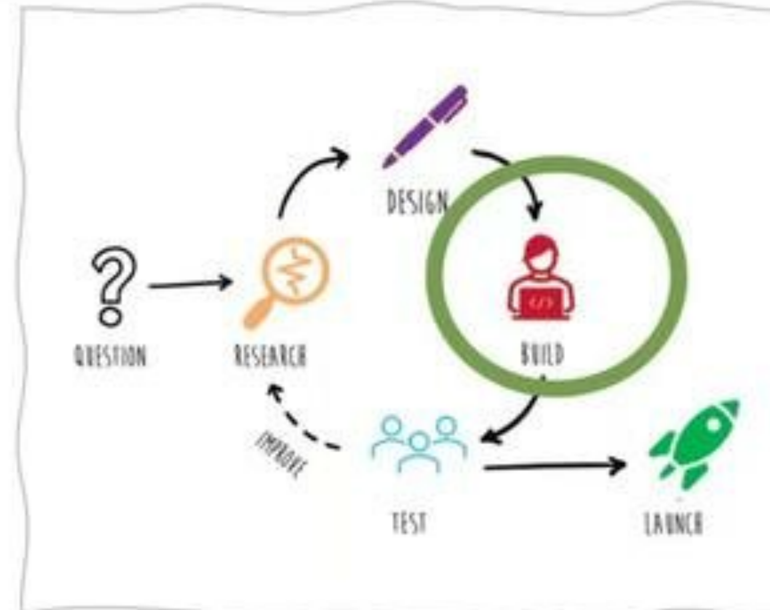
Design Priority:

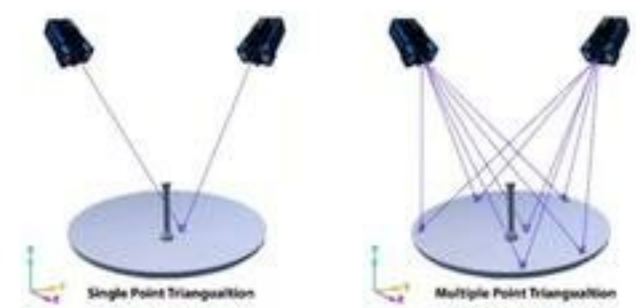
- High Visual Realism
- Technology used: **Photogrammetry**



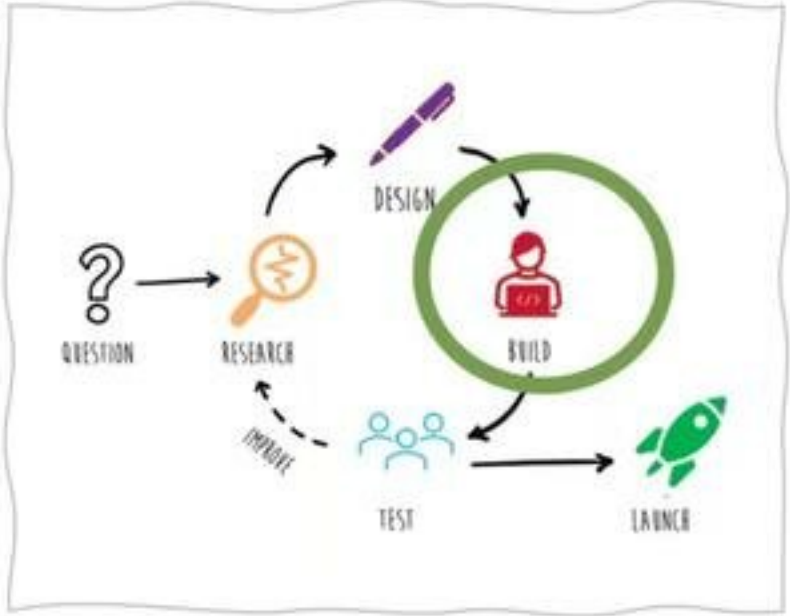


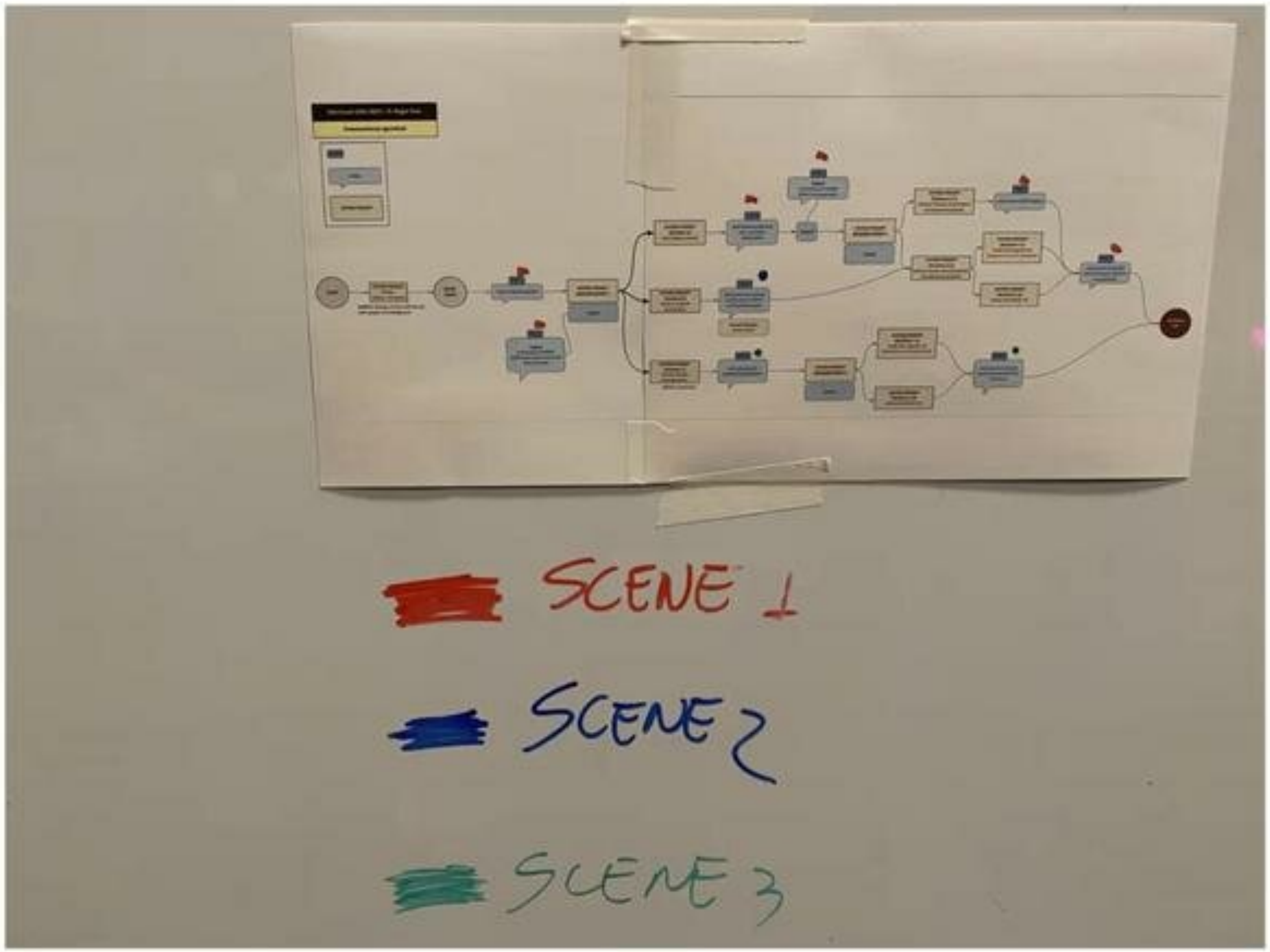


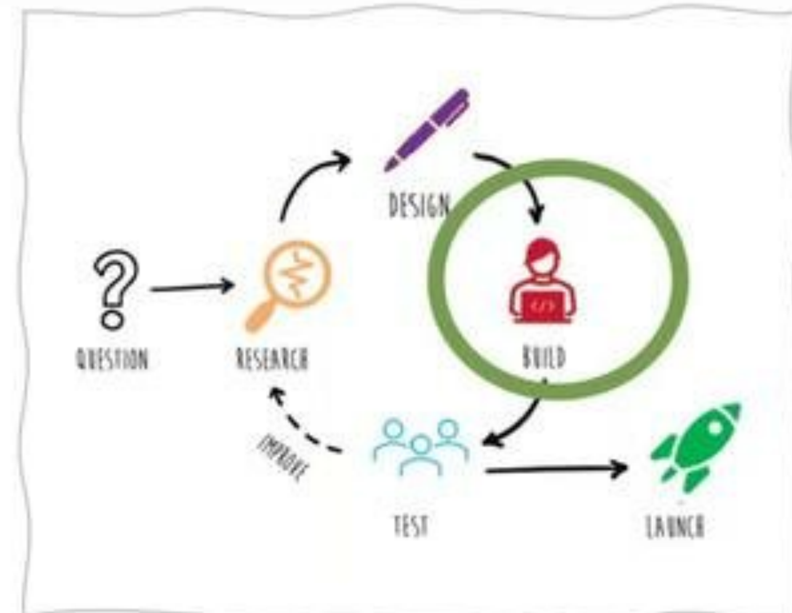


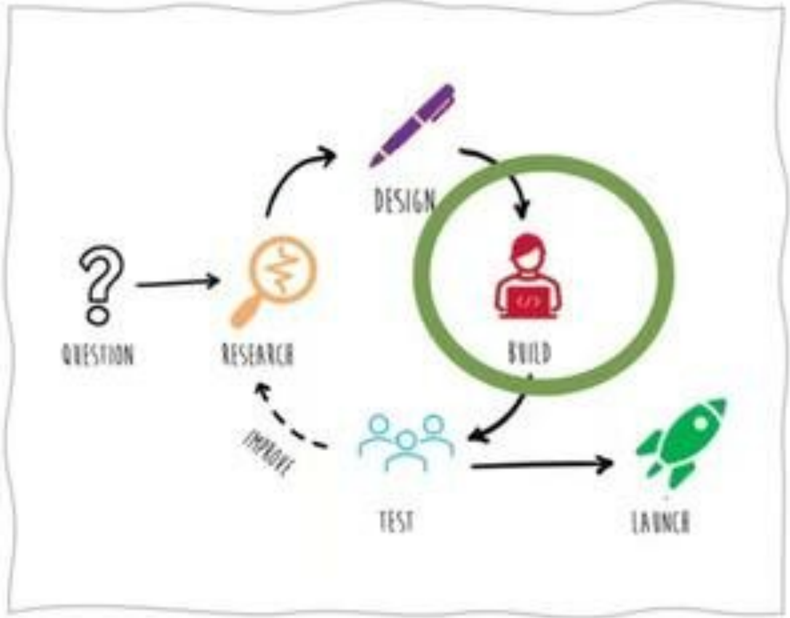


Photogrammetry


DESIGN
QUESTION
RESEARCH
BUILD
IMPROVE
TEST
LAUNCH


SCENE 1
SCENE 2
SCENE 3

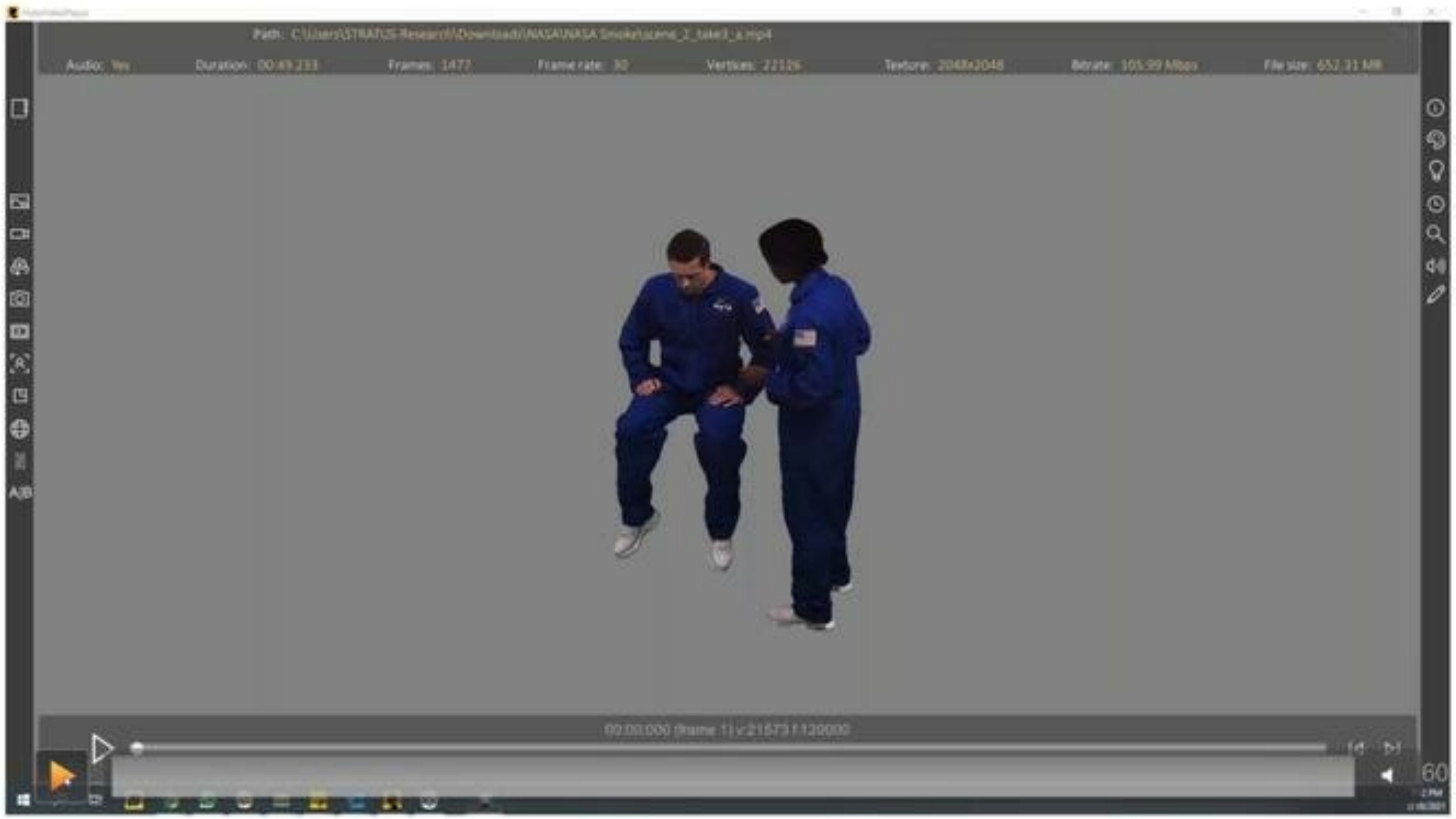

QUESTION
RESEARCH
DESIGN
BUILD
TEST
IMPROVE
LAUNCH

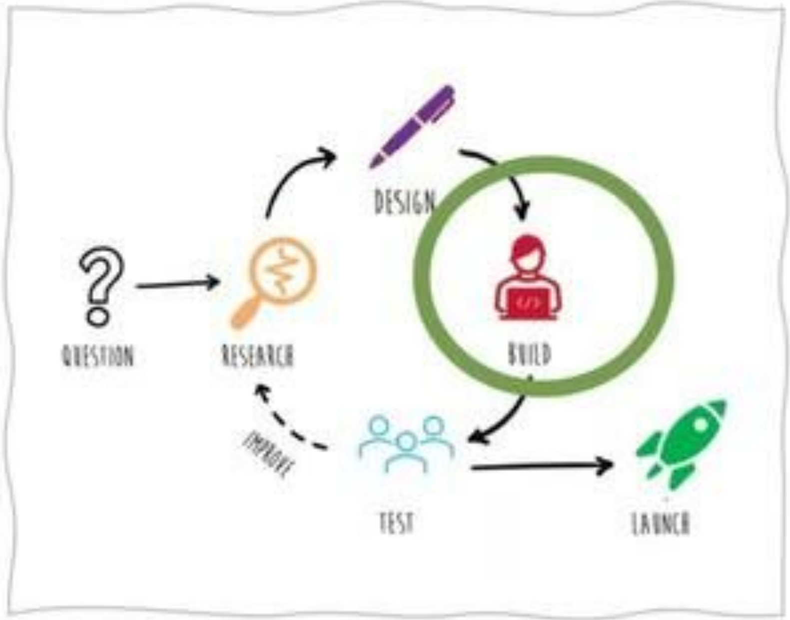

DESIGN
QUESTION
RESEARCH
BUILD
IMPROVE
TEST
LAUNCH

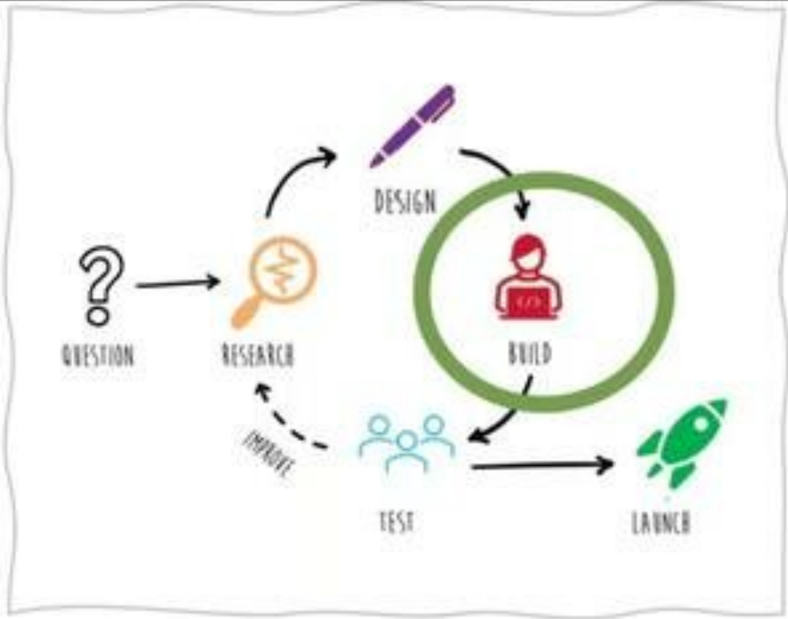
Photogrammetry


Path: C:\Users\STRATUS-Research\Downloads\NASA\NASA Smoke\scene_2_take3_a.mp4
Audio: Yes
Duration: 00:49.233
Frames: 1477
Frame rate: 30
Vertices: 22126
Texture: 2048x2048
Bitrate: 105.99 Mbps
File size: 652.31 MB

Unreal Game Engine + Photogrammetry Videos

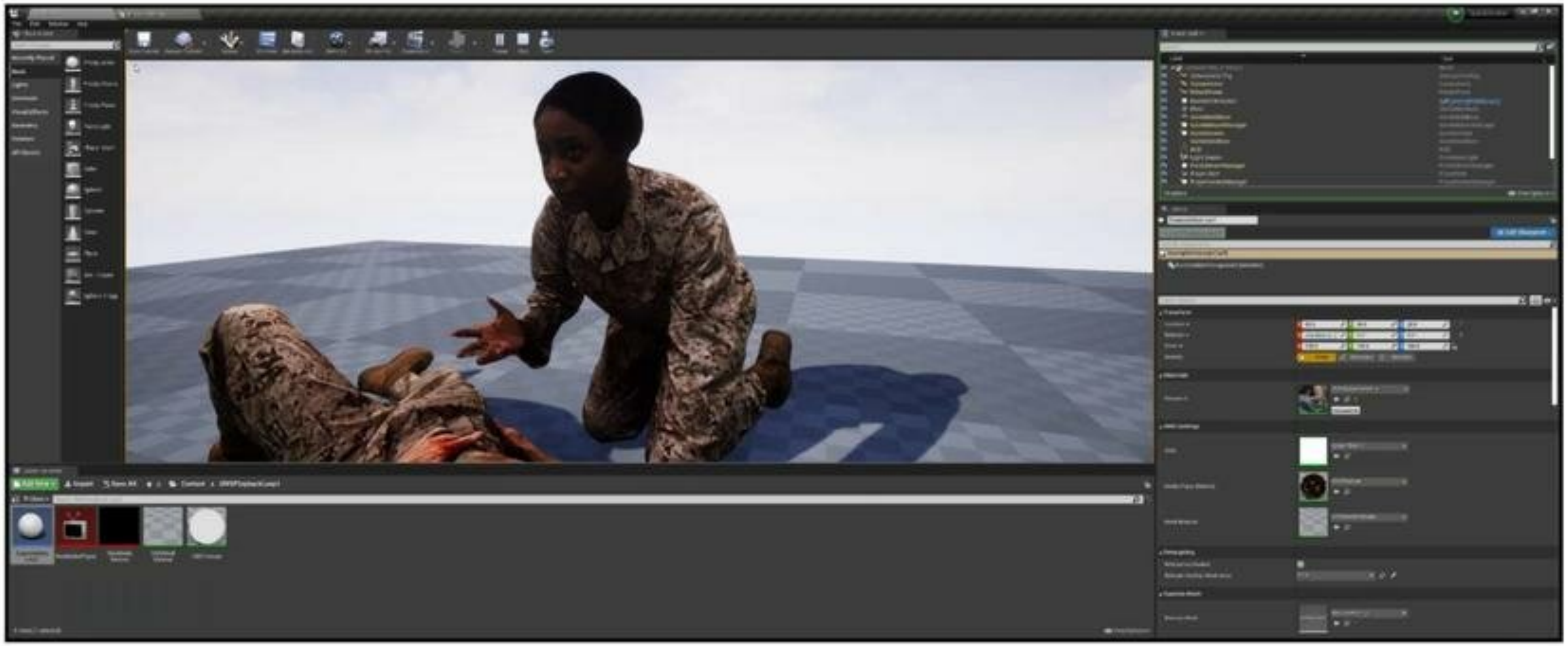

Path:
Audio: Yes
Duration: 00:49.233
Frames: 1477
Frame rate: 30
Vertices: 22126
Texture: 2048x2048
Bitrate:
File size:


QUESTION
RESEARCH
DESIGN
BUILD
TEST
LAUNCH
IMPROVE

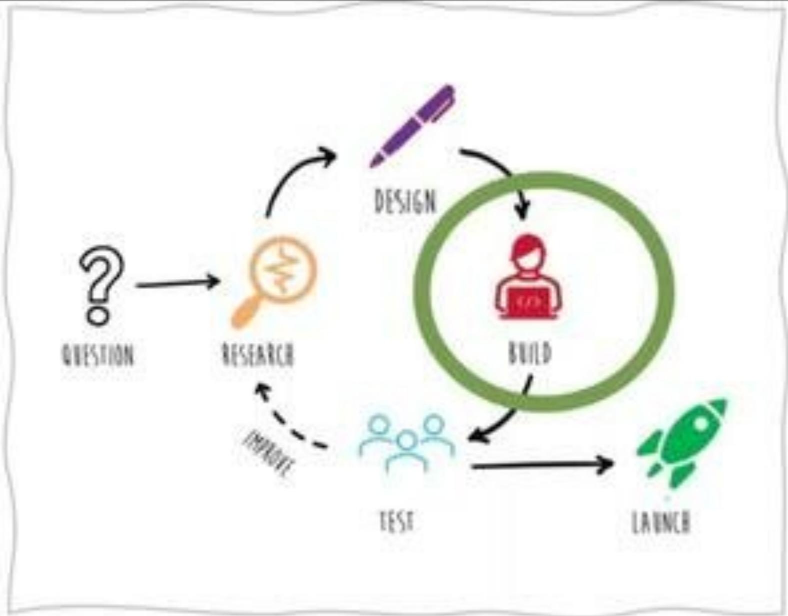


Unreal Game Engine + Photogrammetry Videos

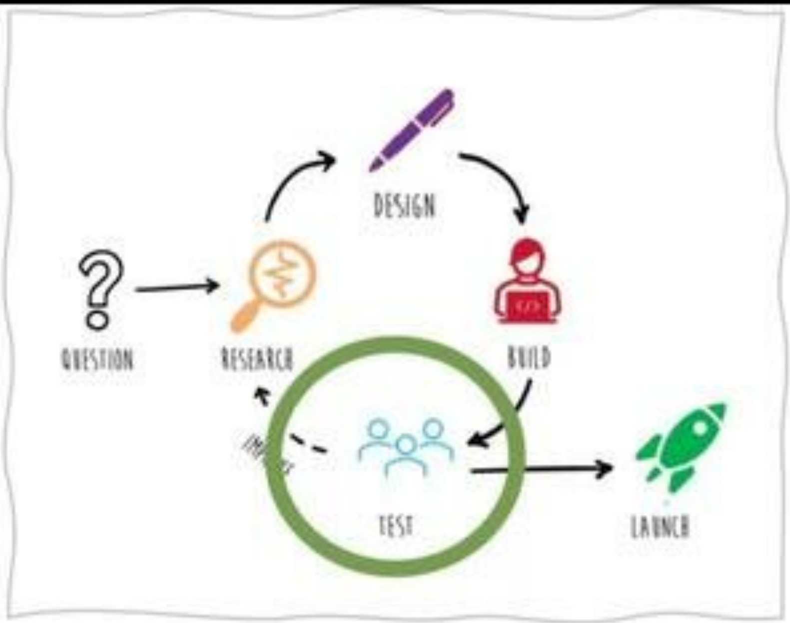

00:01.29



SpaceX Use Case



Test the Application: Experiment Setup



- Level of Knowledge (Using a knowledge test)
- Workload (using NASA TLX and HR/HRV)
- Engagement: Using EEG data (Engagement Index)
- Immersion (IPQ tool)

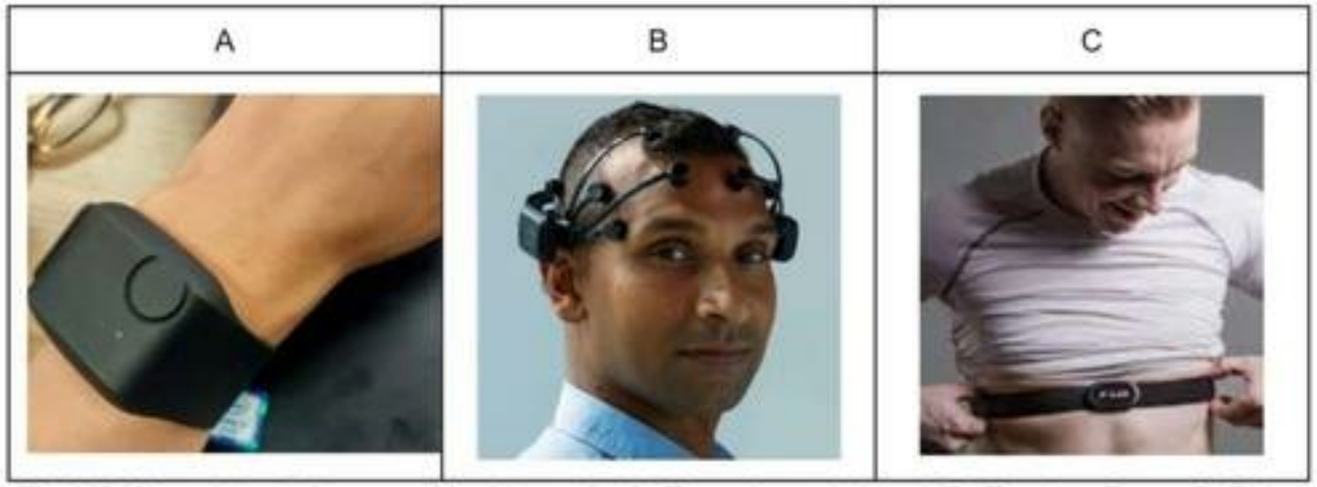
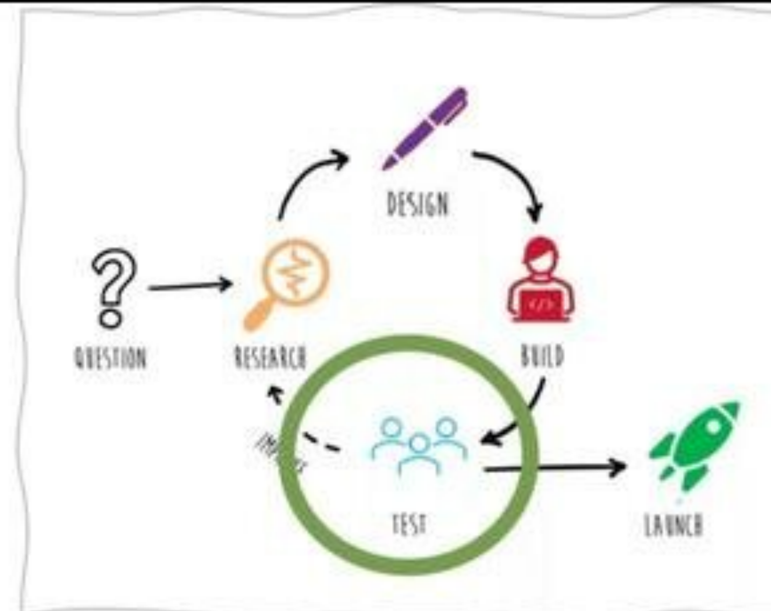


Fig. Y2-Wearable devices used in this study, A: Empatica wristband, B: Emotive Epox, C: Polar chest band

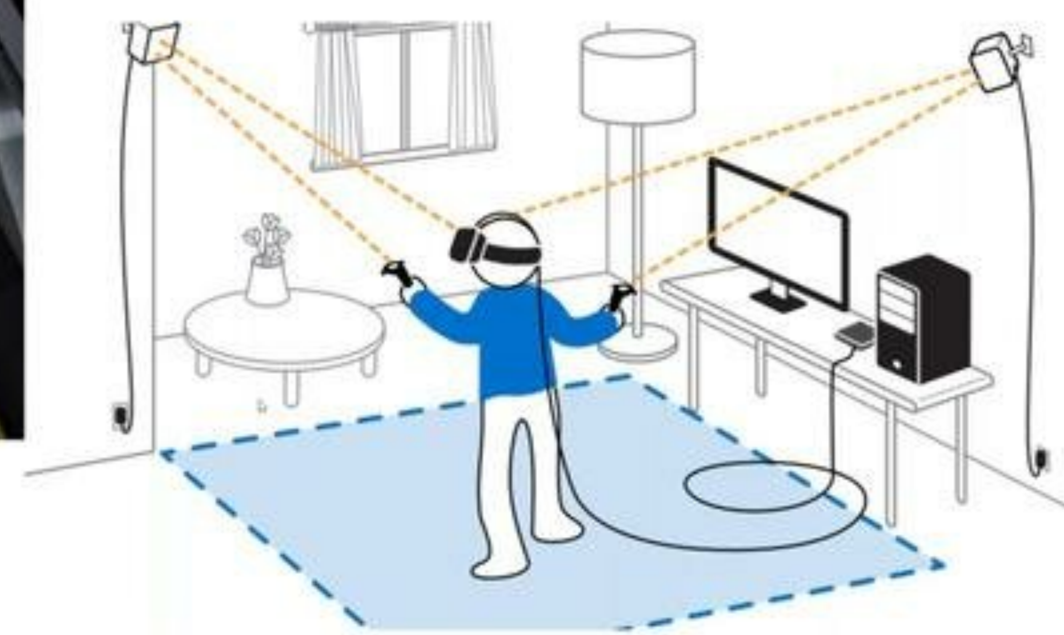
Experiment: Data Collection Tools



Experiment: Data Collection Tools

Experiment: Data Collection Tools

Experiment: Data Collection Tools



Creating AR version of this VR Application

- Not a simple conversion!

AR Application

- Objects are captured using volumetric video capturing technology

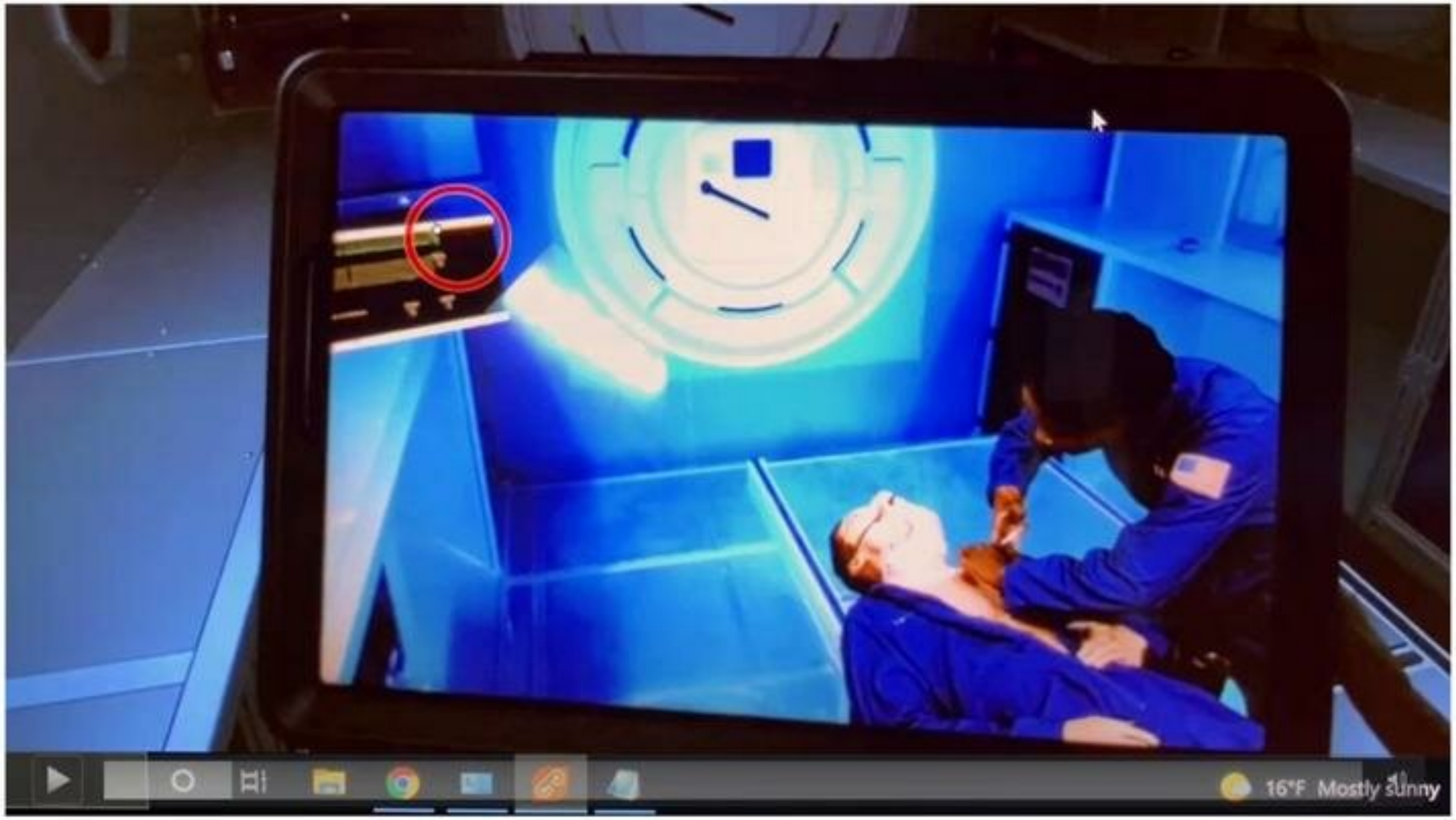
AR Application

- Objects are captured using volumetric video capturing technology

Type of AR Experience

- Hand-held
- Marker-based

Testing: How Eye Tracker Can Help to Test the Design



Use Case #2

- VR
- Military + Healthcare

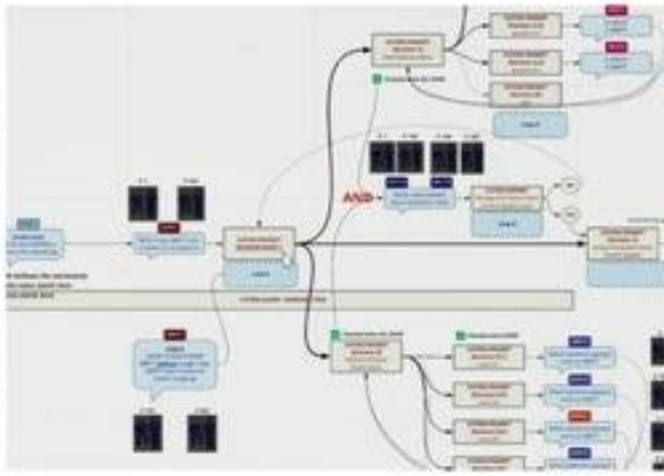
Military Clinical Support

A VR Prototype for DoD project

A VR Prototype for DoD project

A VR Prototype for DoD project

Type of VR Experience: Narrative Branching



Use Case #3

- VR
- Transportation

VR Simulator in Automated Driving

Let's start with questions!

Ironies of Automation!

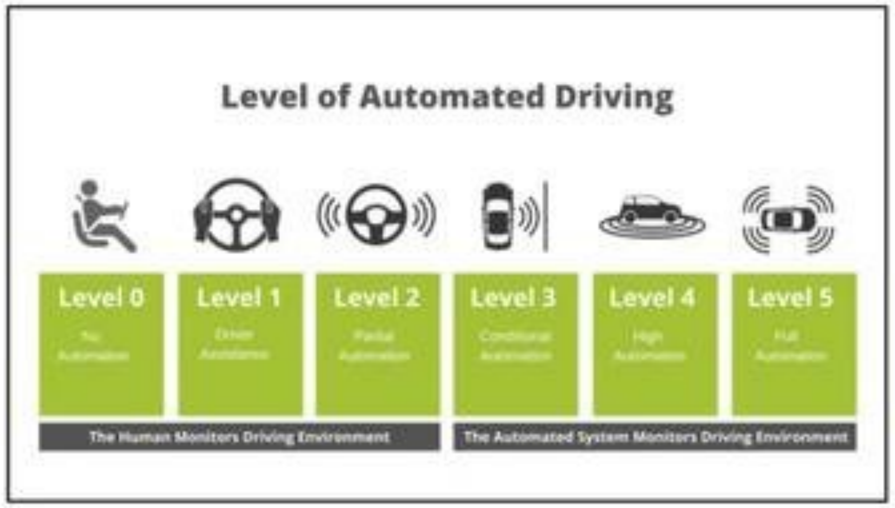
Automation Complacency

How to improve self-driving safety and driving experience?

Can VR training simulator help first-time users of highly automated driving?

Automated Driving Simulator to understand:

- Human trust to automation
- Misuse, Disuse
- Distraction (what does it mean in self-driving?)
- Driving behavior in different level of automaton, safety



Driving Simulators

Full Car

Semi-Cave

Full-Monitor

Simple-Monitor

Higher fidelity (visual, motion, psychologic)
Higher costs (development, maintenance, space)

Lower fidelity
Lower costs

Which simulator is the best?


Full Car


Semi-Cave


Full-Monitor


Simple-Monitor

["it depends"]

- **Scope :** research, training, demo, sales?
- **Scale**
- **Budget**
- **Time**
- **Available Resources**

Can XR technology contribute to this?

["it depends"]

- **Scope** : research, training, demo, sales?
- **Scale**
- **Budget**
- **Time**
- **Available Resources**

example

How to onboard new users to self-driving cars? Car XR help?

No Fidelity

(In interaction)

Low Fidelity

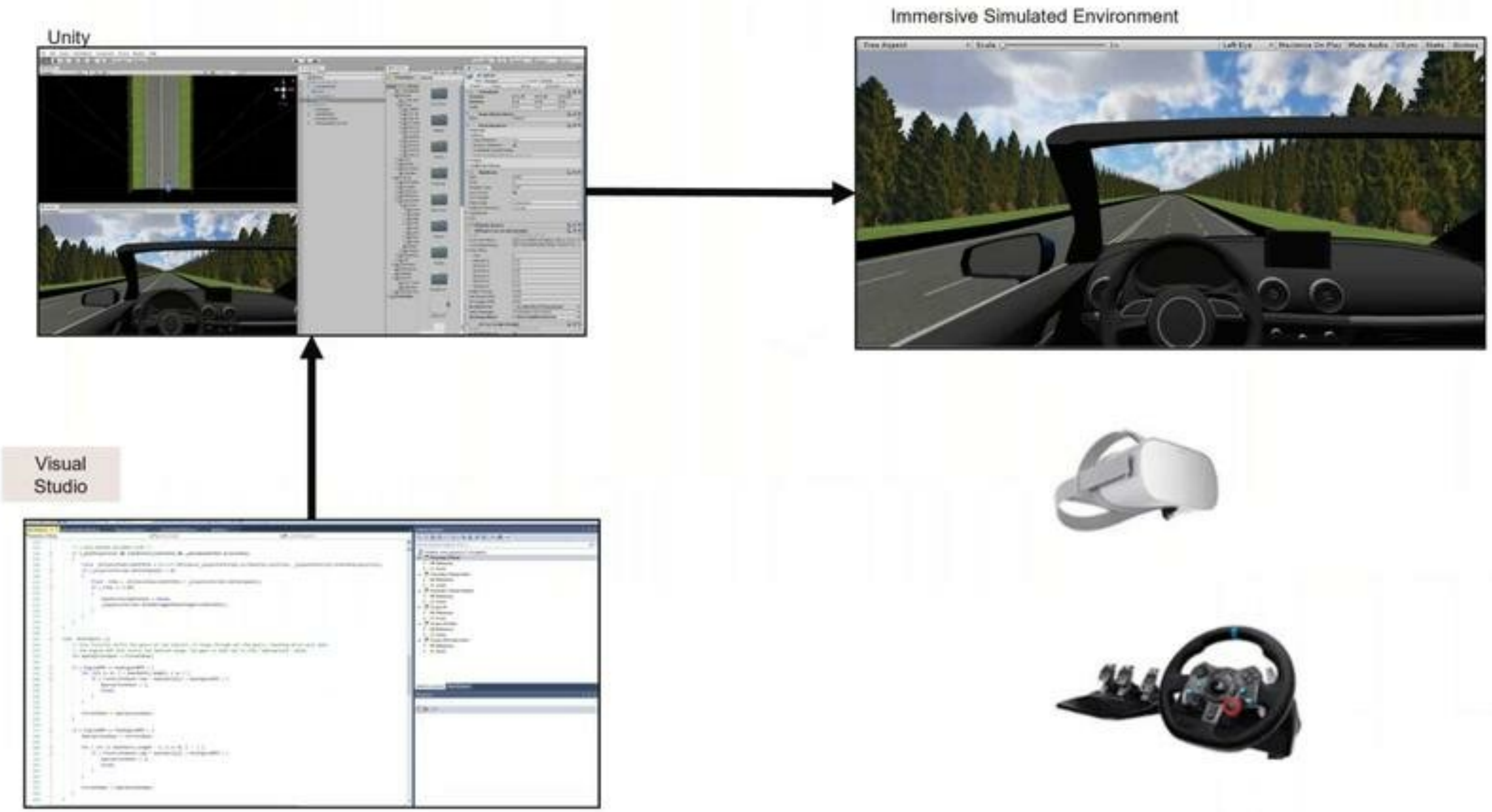
High Fidelity

- How to onboard new users to self-driving cars? Car VR help?
- How interaction fidelity of VR simulator matters in learning cognitive and sensory motoric skills


Applied Ergonomics

Virtual reality tour for first-time users of highly automated cars: Comparing the effects of virtual environments with different levels of interaction fidelity

VR as a Training System in Highly Automated Driving



VR Application: Prototype 1

VR Application: Prototype 1

Fig. A.1. A screenshot from the start page of the VR tour.

Fig. A.2. Screenshot from start first step of the VR tour: learn about self driving.

VR Application: Prototype 1

Fig. A.1. A screenshot from the start page of the VR tour.

Fig. A.2. Screenshot from start first step of the VR tour: learn about self driving.

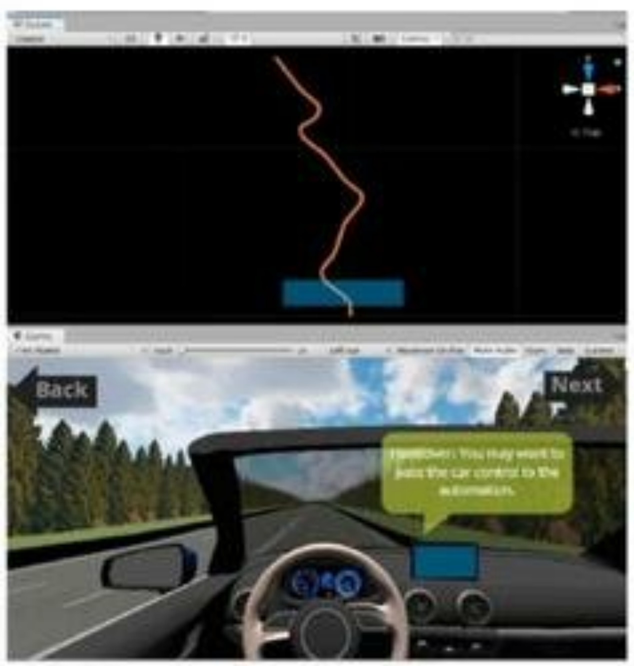


Fig. A.3. Screenshot from handover practice in the VR tour.

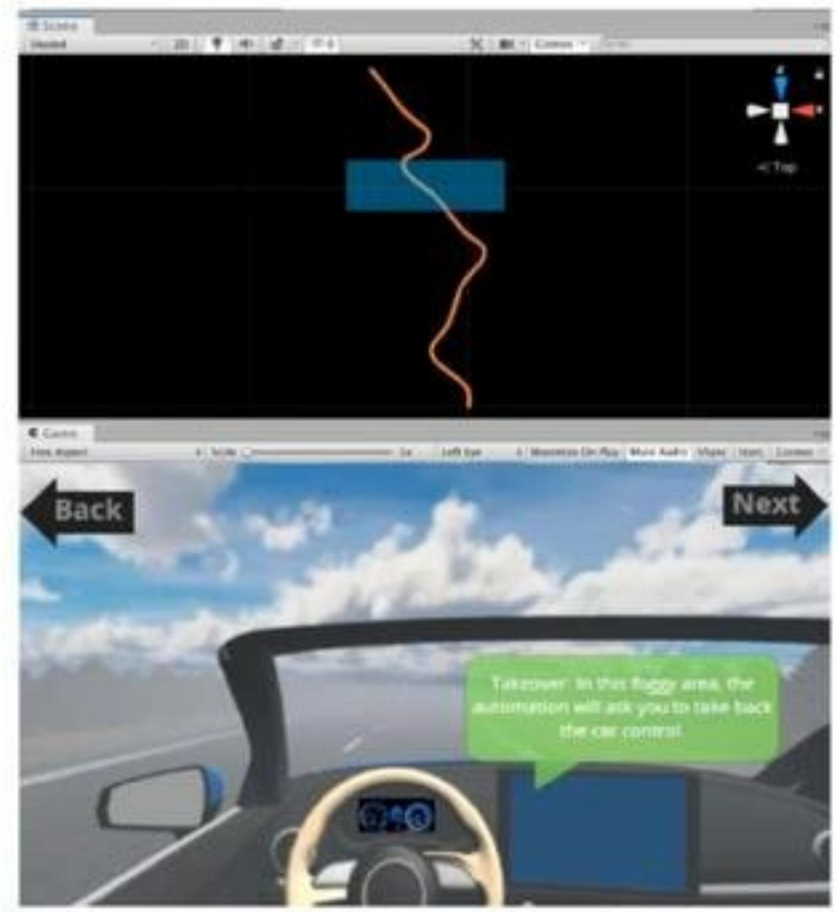


Fig. A.4. Screenshot from critical takeover practice in the VR tour (approaching a road section with high-density fog).

VR Application: Prototype 2

VR Application: Prototype 2

Experiment: Data Collection Tools

Used for the
secondary task

VR Headset

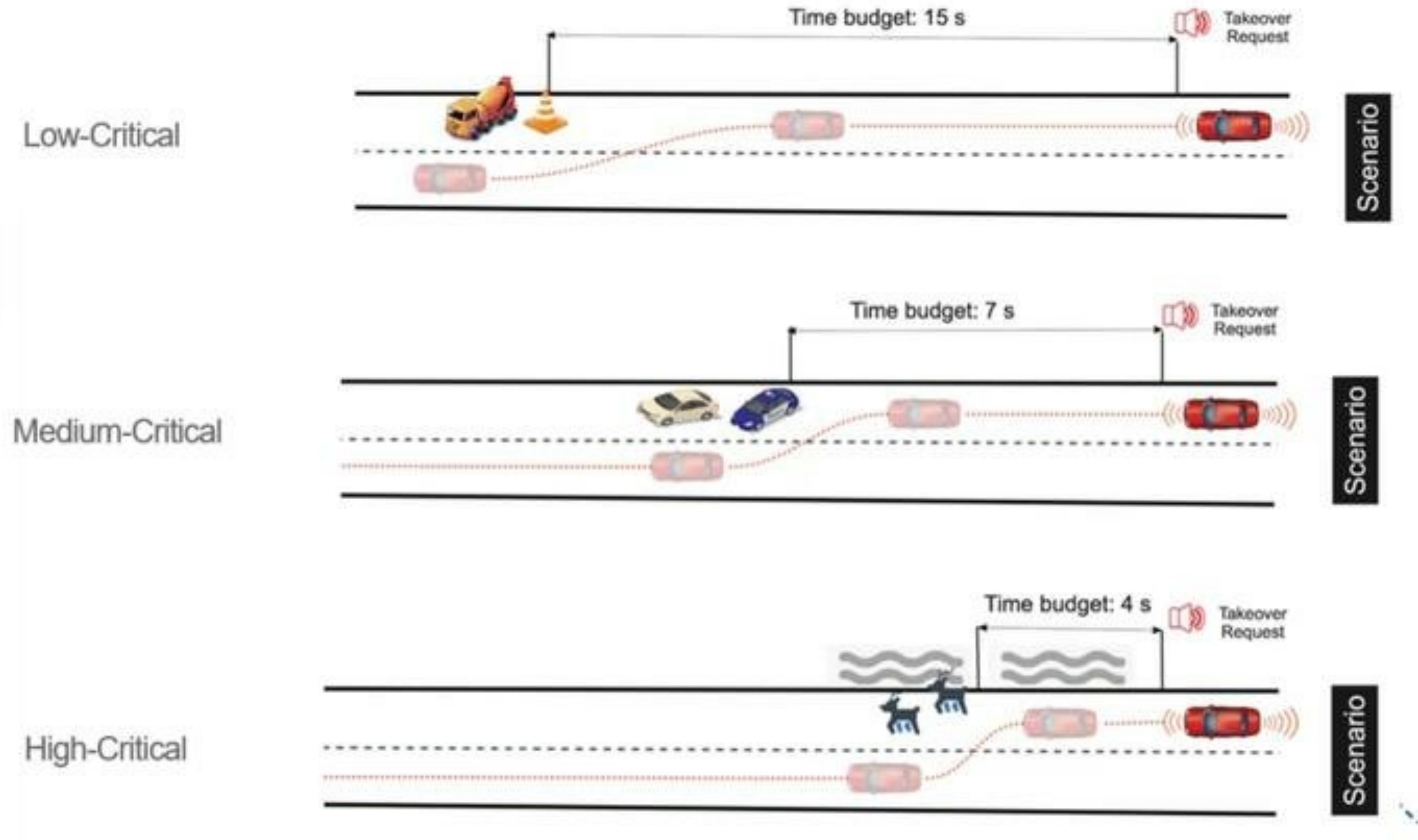
For HF Interaction

For LF Interaction

Fig. 3. Driving simulator set-up.

Experiment: Testing Scenarios

Non-Scheduled TOR Scenarios



Scenarios

Low Density Fog

High Density Fog

Partially Missed Lane Markings

Part

AR Applications

Use Case #3

- AR
- Healthcare

AR-Coach as Clinical Guidance

Experts Panel + Card Sorting

Essential capabilities of XR platforms for space applications were identified.

Task Analysis

A process model of a POCUS-guided procedure to diagnose a potentially life-threatening condition was created.

Basic Design

Using Unity 3D, first version of the concept was designed.

Conversational Coach

Using Metahuman and Unreal, a coach was designed and conversations were recorded using LiveLink app.

Metahuman + Unreal

Complete Design

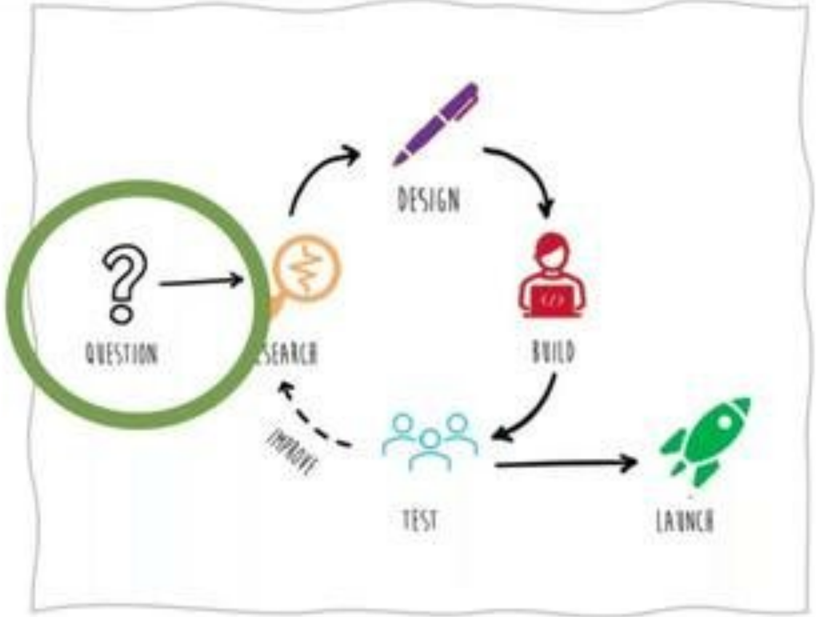
After getting feedback from clinicians and human factors experts, design layout was modified. Voice-based interaction was incorporated.

Unity + MRTK

Deployment

Features (visualizations, conversations branches, voice-command, gesture control, etc.) were tested and the application was deployed on HoloLens2.

HoloLens



- Usability of XR technology as in-flight a clinical guidance for space health during long-duration space missions

STRATUS
CENTER FOR MEDICAL SIMULATION

Human Factors &
Cognitive Engineering Lab

HARVARD
MEDICAL SCHOOL

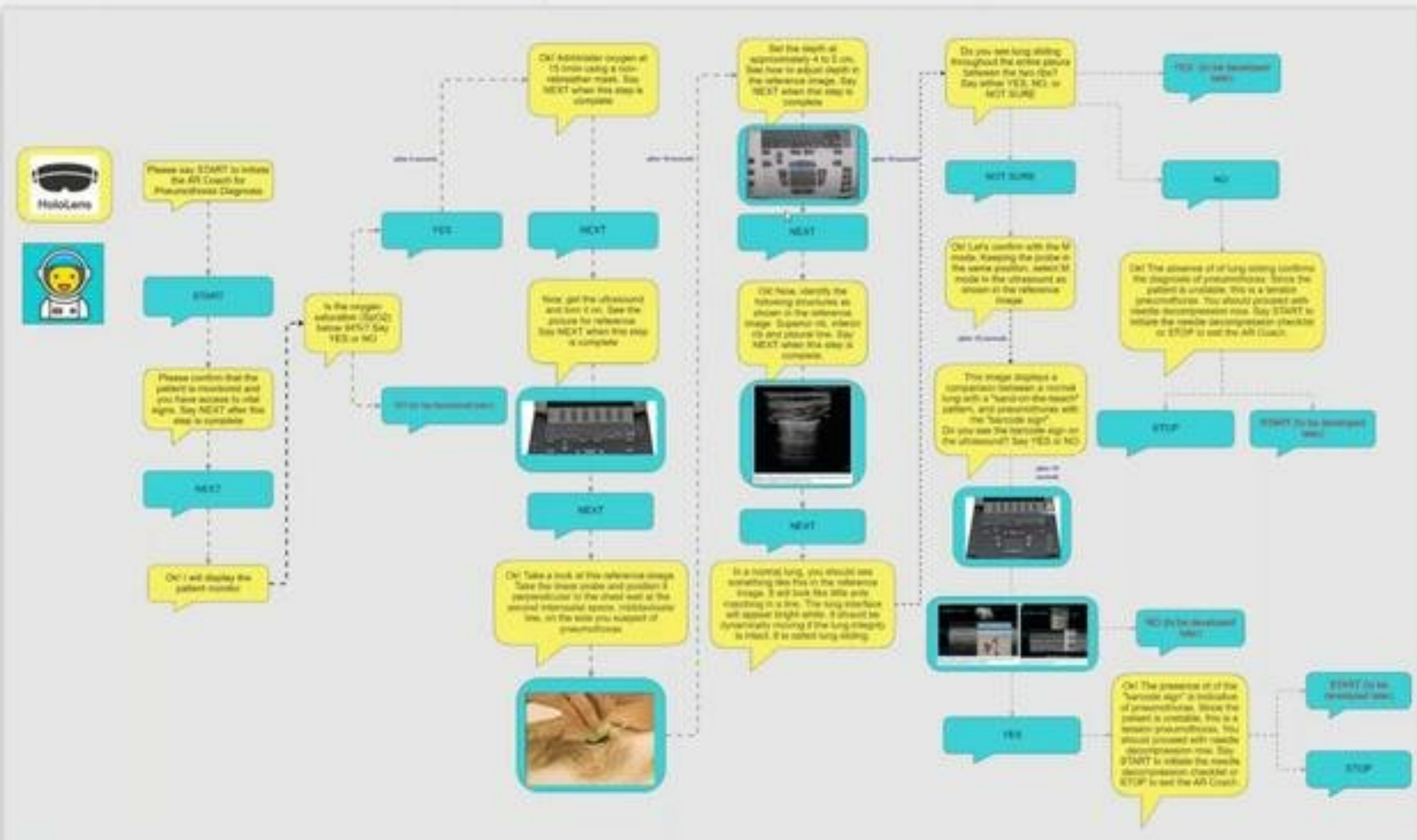
TRANSLATIONAL
RESEARCH INSTITUTE FOR
SPACE HEALTH

Cognitive Task Analysis (CTA)

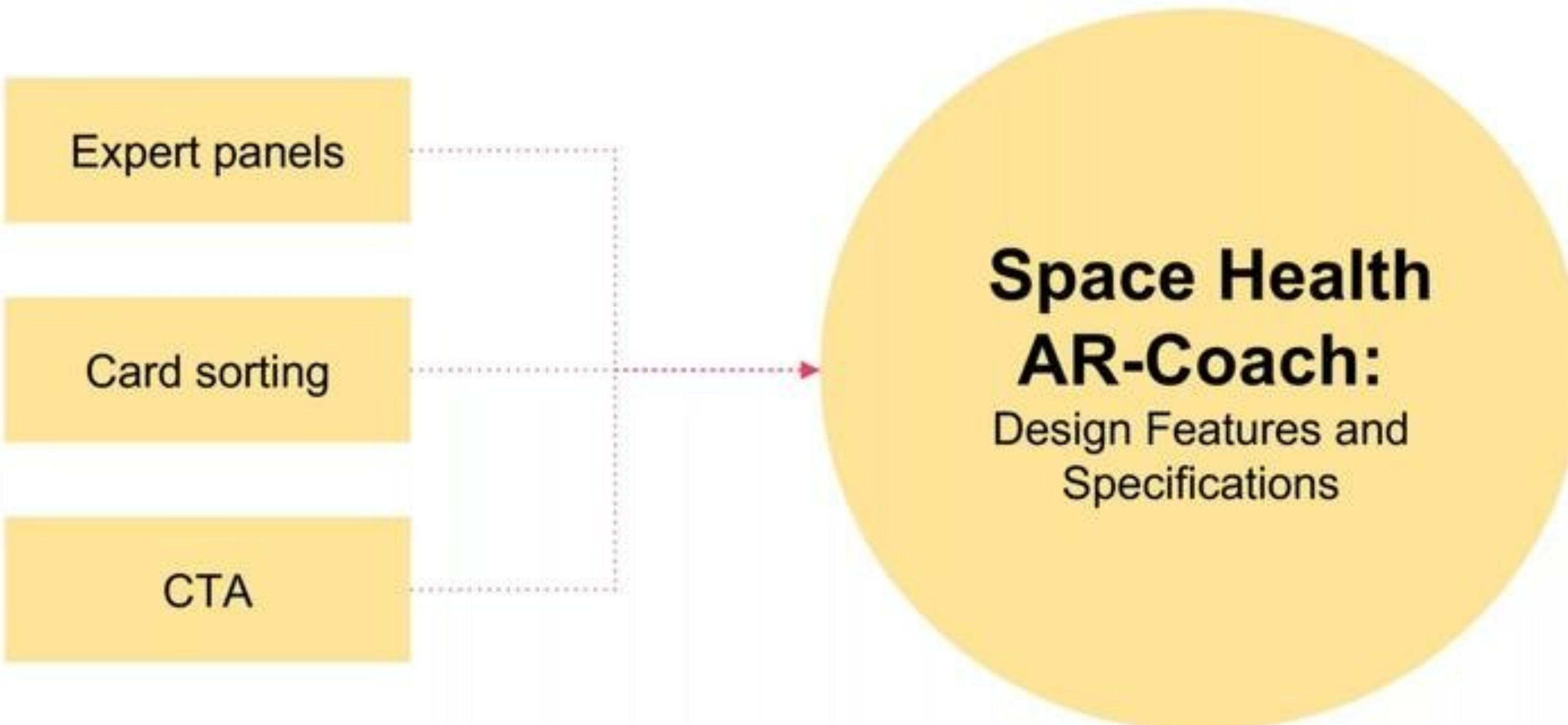
AR-Coach: Using Augmented Reality (AR) for Real-Time Clinical Guidance During Medical Emergencies on Deep Space Exploration Missions

M. Ebnali, A. J. Goldsmith, B. Burian , B. Atamna , N. M. Duggan , C. Fischetti , S. Yule , R. Dias

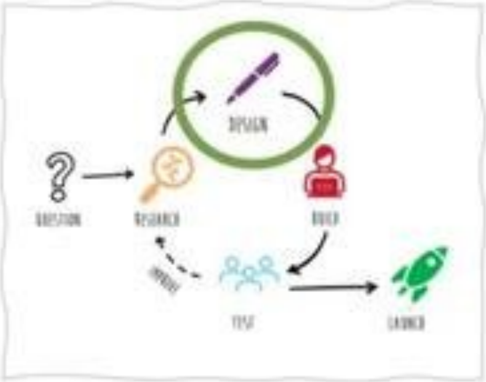
Frame 1



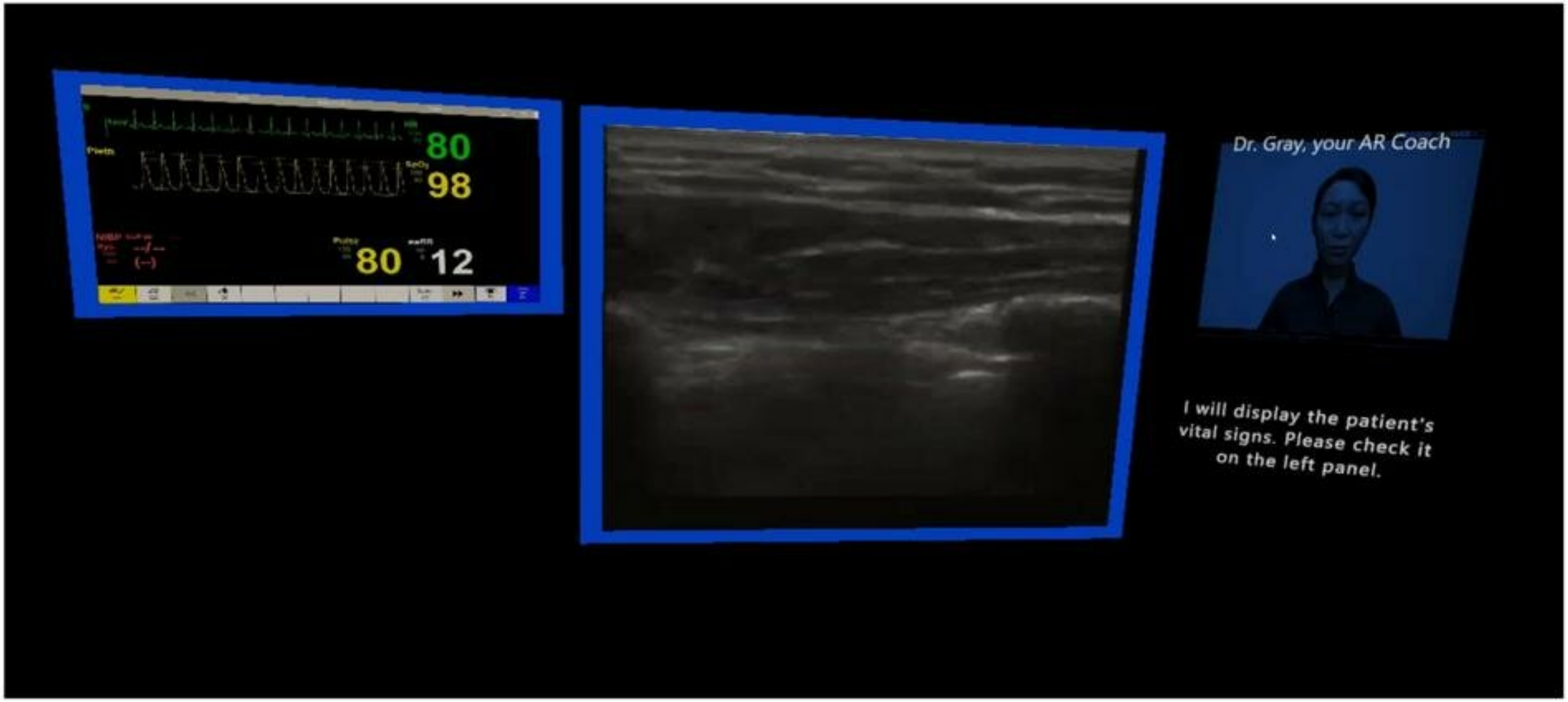
Specifying Design Features



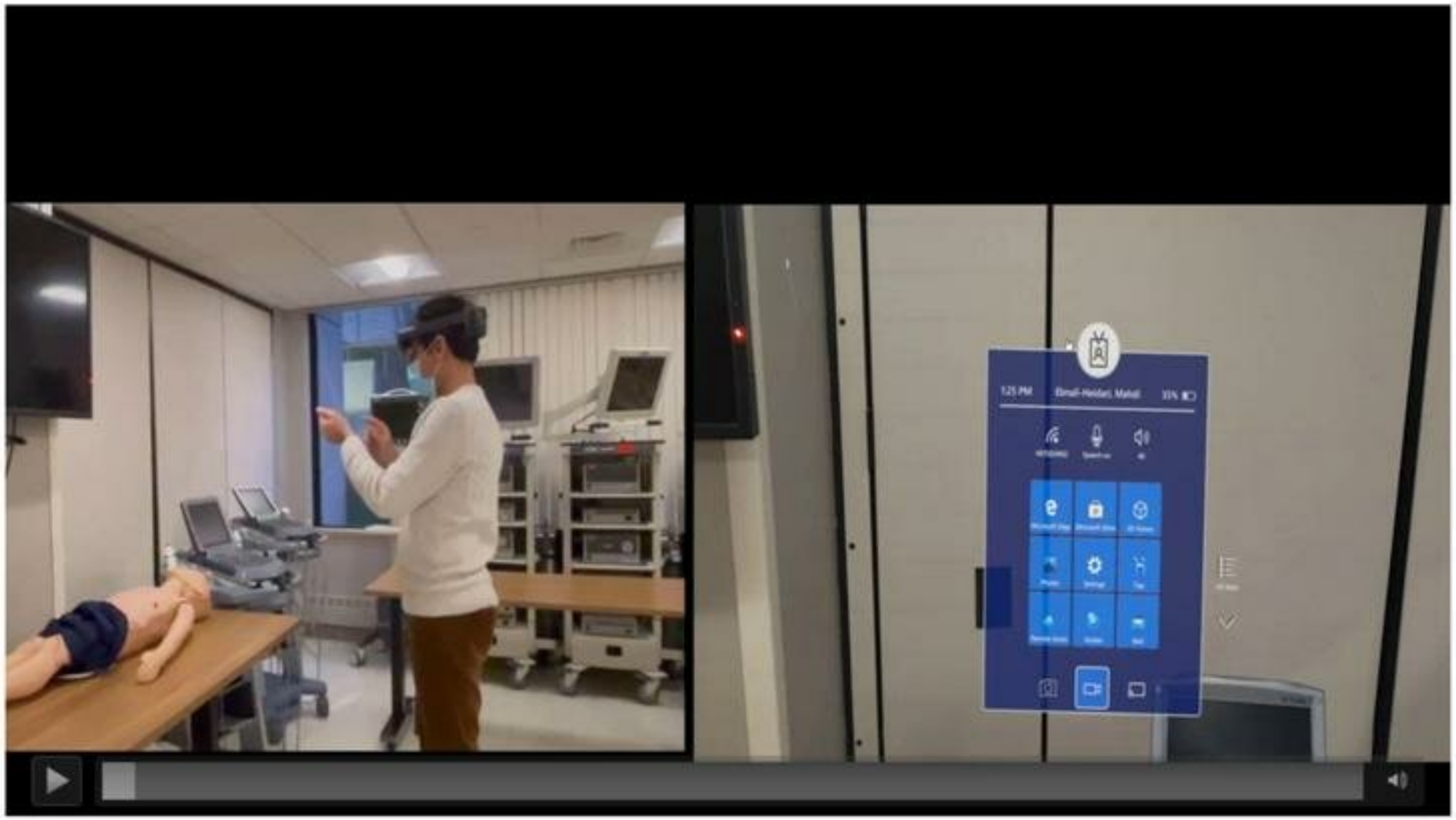
Dirty Prototype (Low Fid)



Prototype Iteration 2



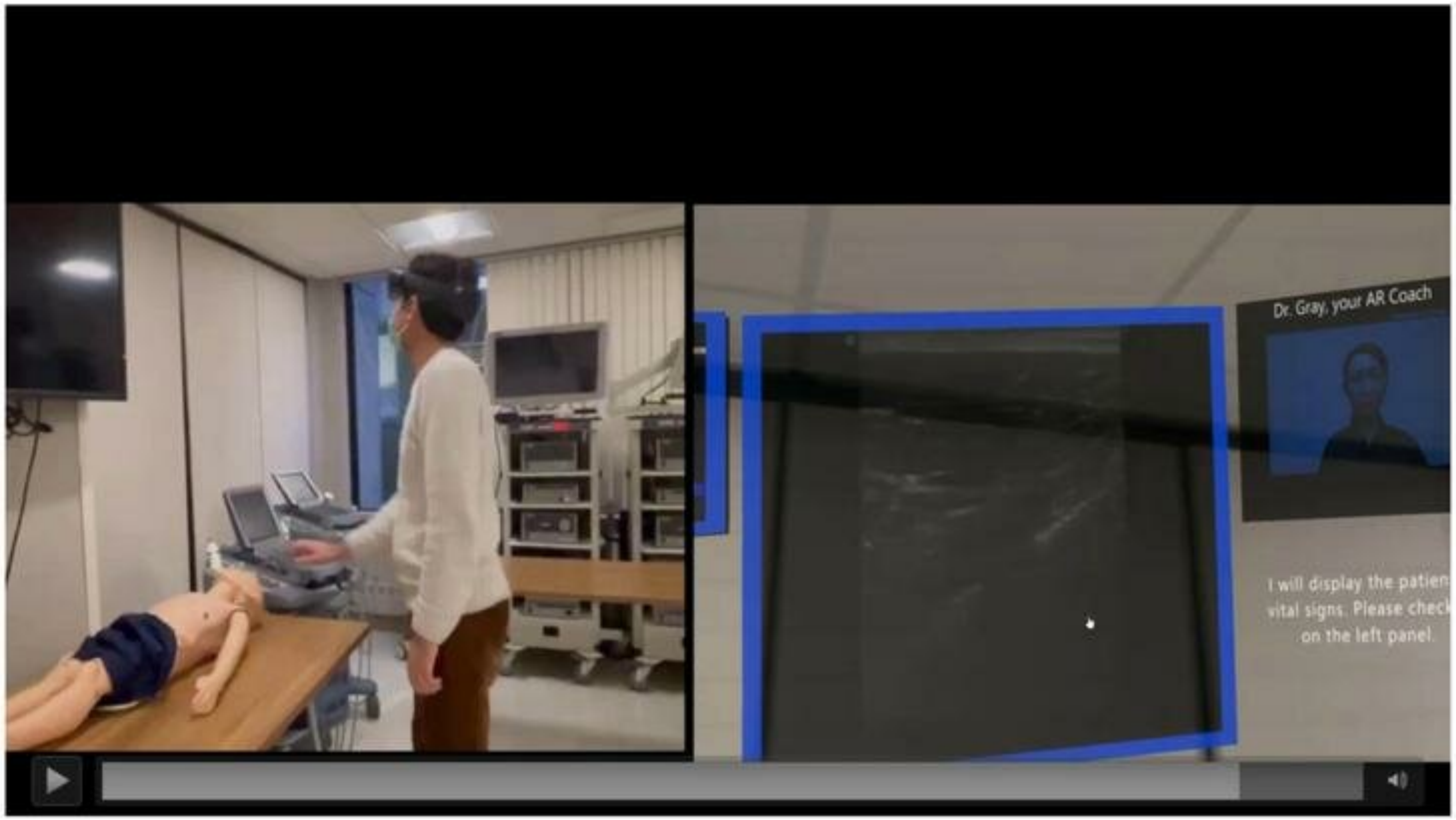
Interaction Testing



Interaction Testing

Interaction Testing

Interaction Testing

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99
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12


Simulation
XR Foundation
XR Design Process
VR Use Cases
AR Use Cases

Thank you!

Mahdi Ebnali, PhD

Any question? please contact me at:
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Or scan this QR code to connect on LinkedIn.

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