

# 3D Web Programming

Fivos DOGANIS

# whoami

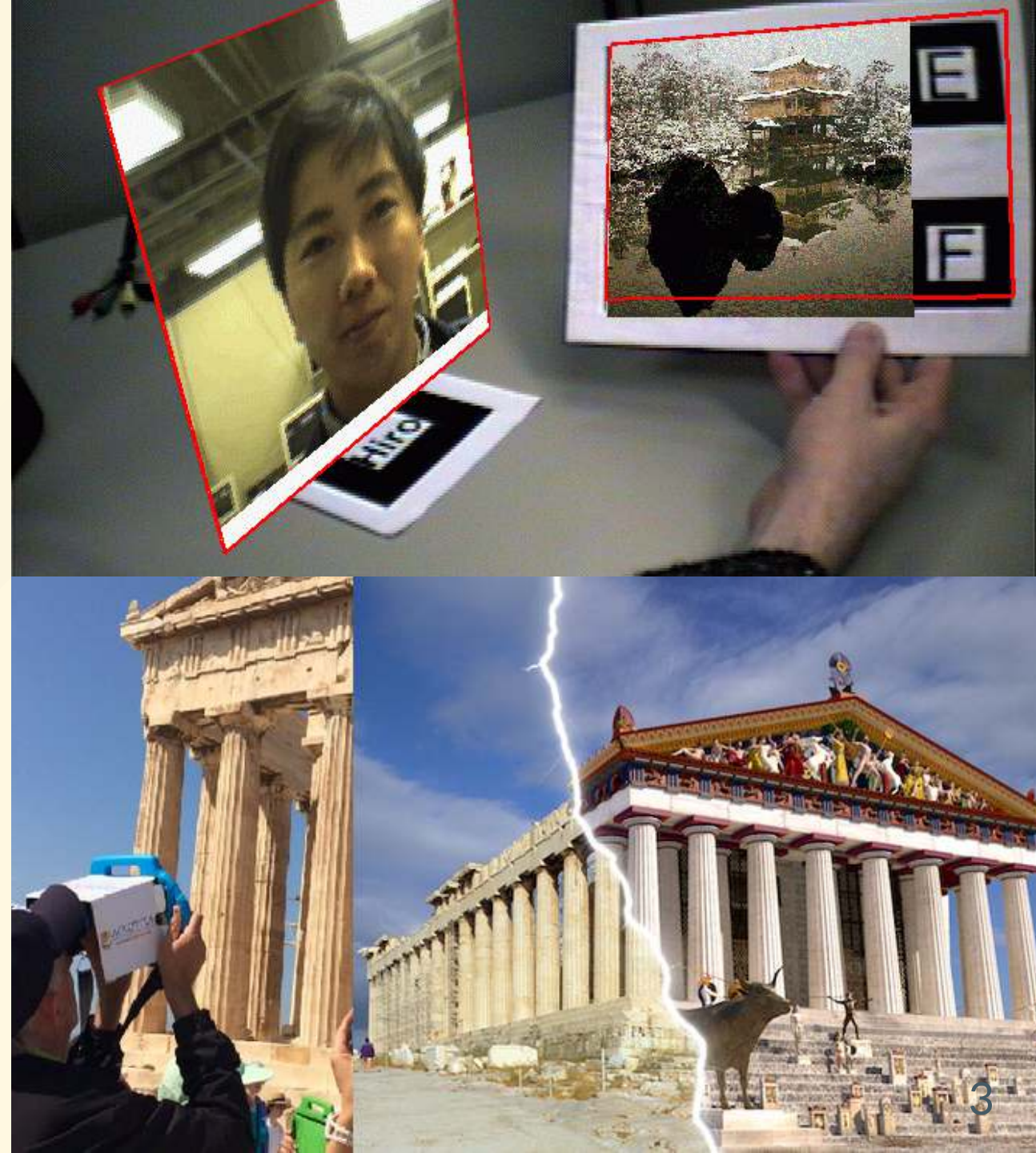
 [linkedin.com/in/fivosdoganis](https://www.linkedin.com/in/fivosdoganis)

 [fivos.doganis@gmail.com](mailto:fivos.doganis@gmail.com)

 [github.com/fdoganis](https://github.com/fdoganis)

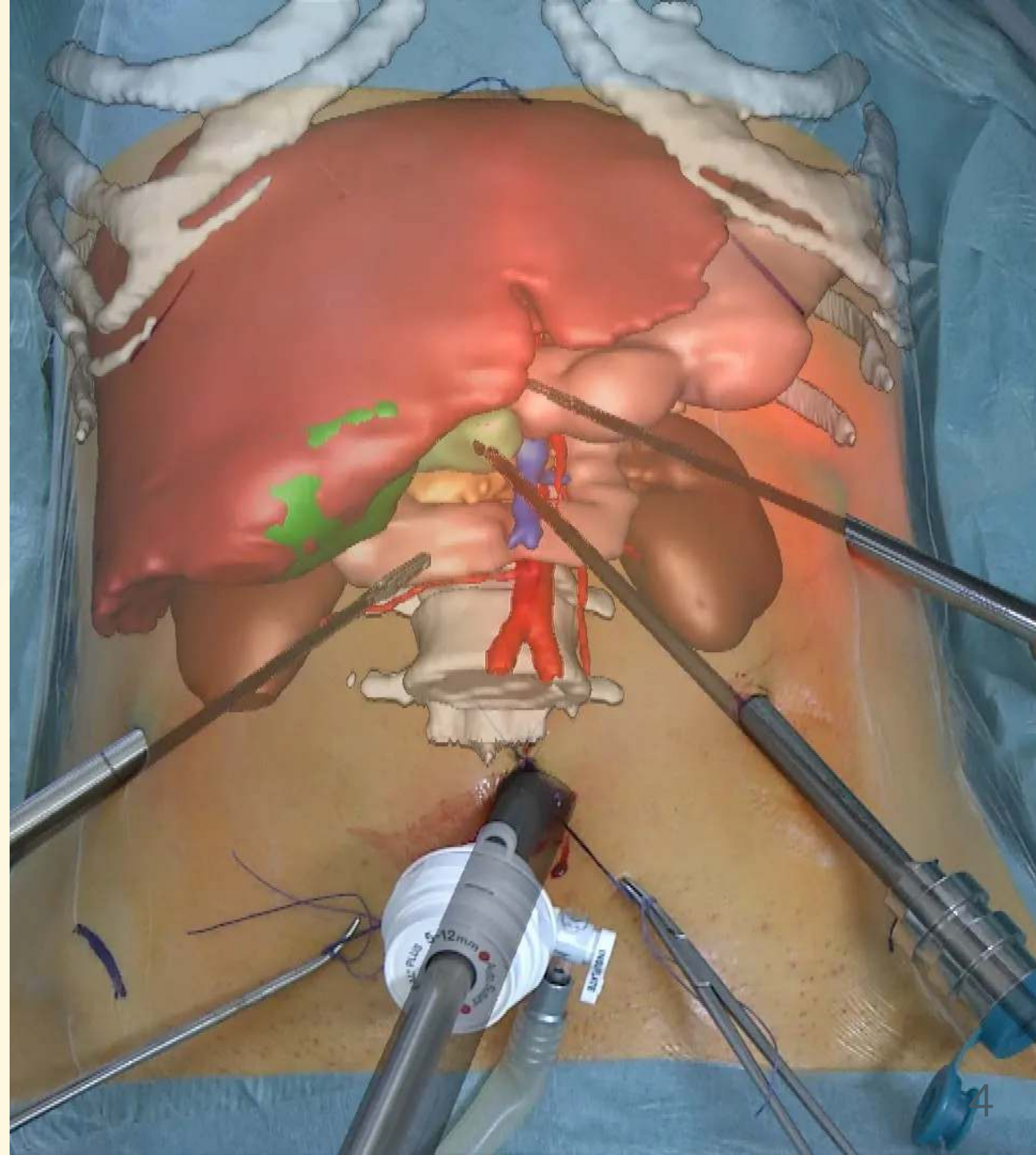
## University of Hull

- Master of Science by Research (2001)  
*Augmented Reality in Archaeology: Registration Issues*



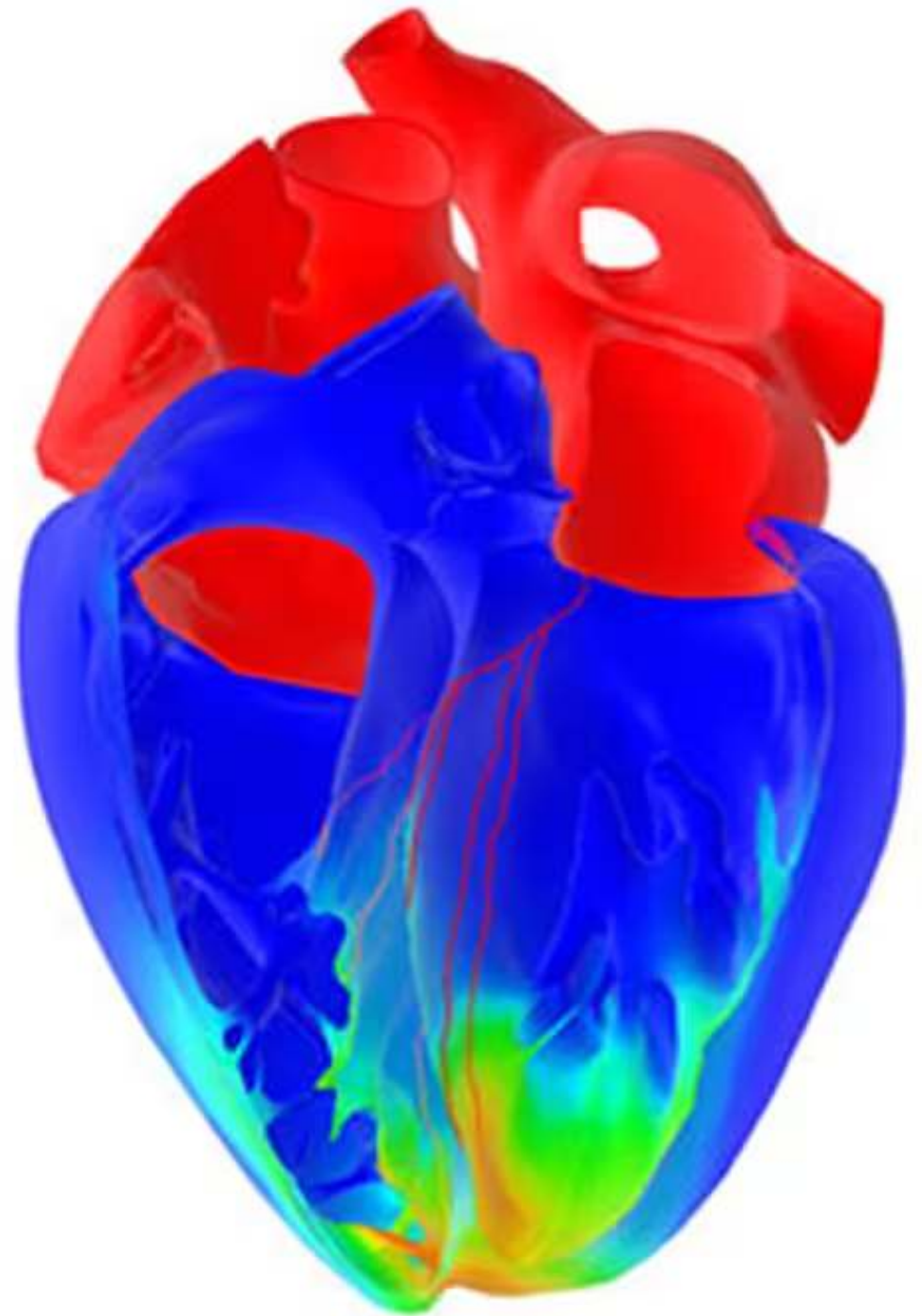
## IRCAD (2002 - 2003)

- Institut de Recherche contre les Cancers de l'Appareil Digestif
- Startup
  - Virtual-Surg team
- Augmented Reality Research Engineer



## Dassault Systèmes (2003+)

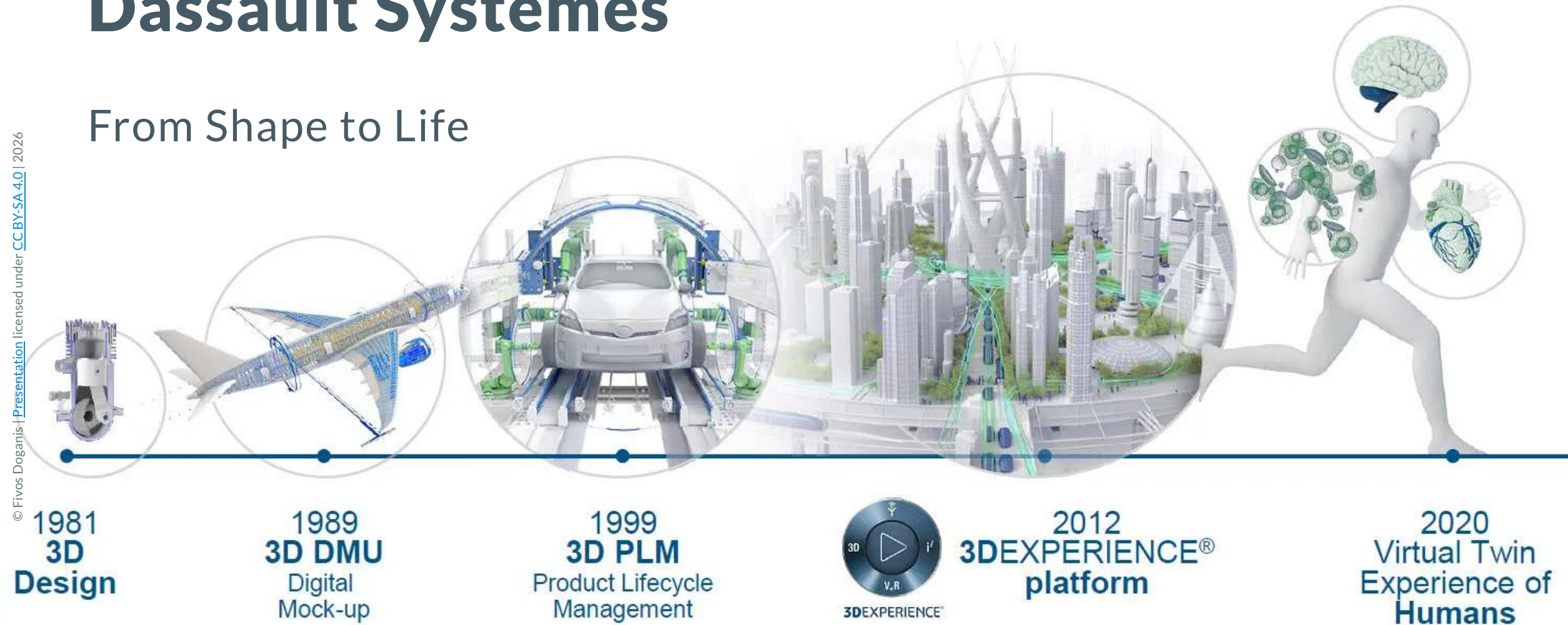
- 3D Visualization Engineer
  - Scenegraph, Materials
  - Geometry, Tessellation
- Virtual and Augmented Reality (XR) Engineer
- XR Research Engineer
- XR Research Manager



# Dassault Systèmes

## From Shape to Life

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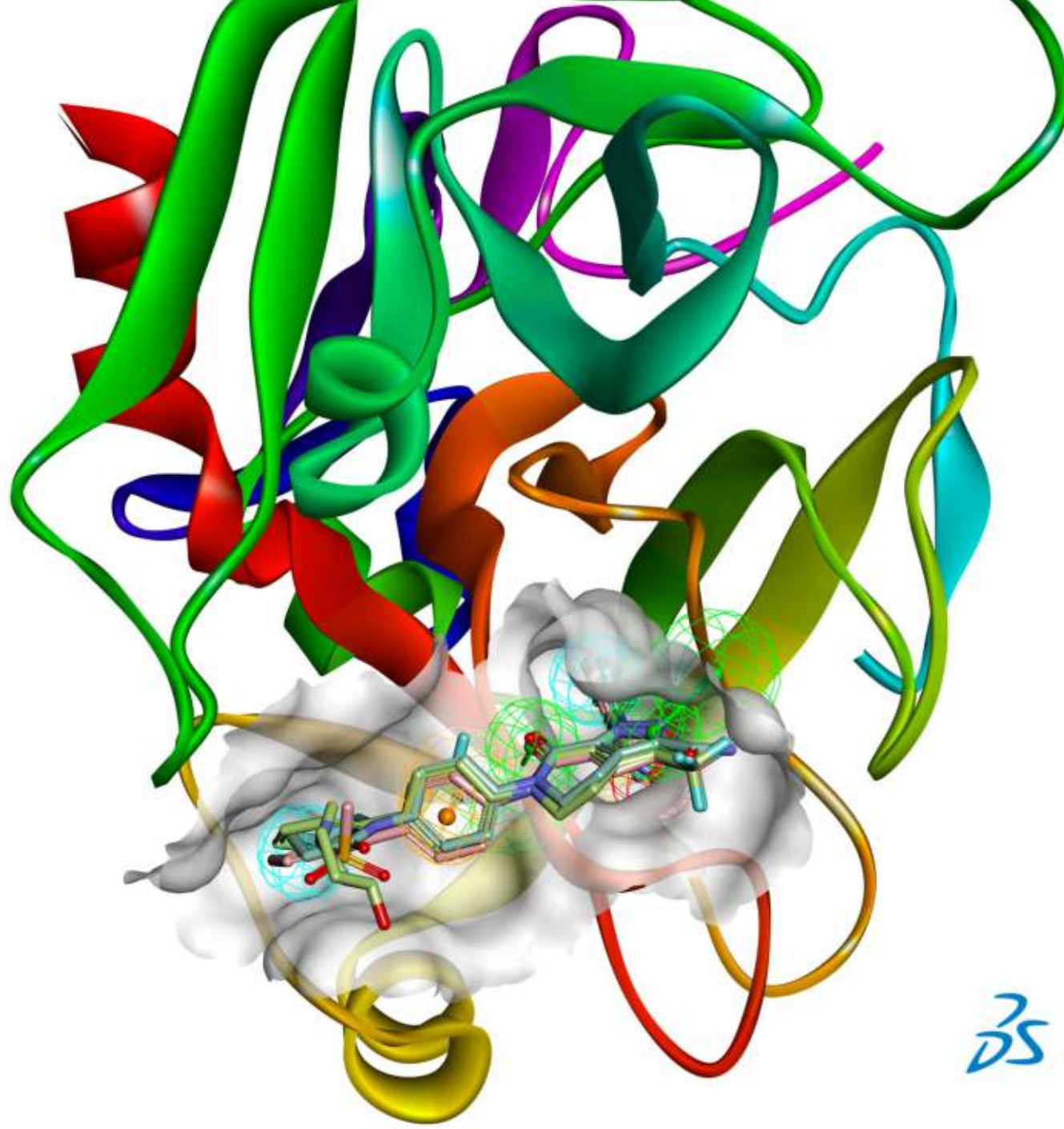


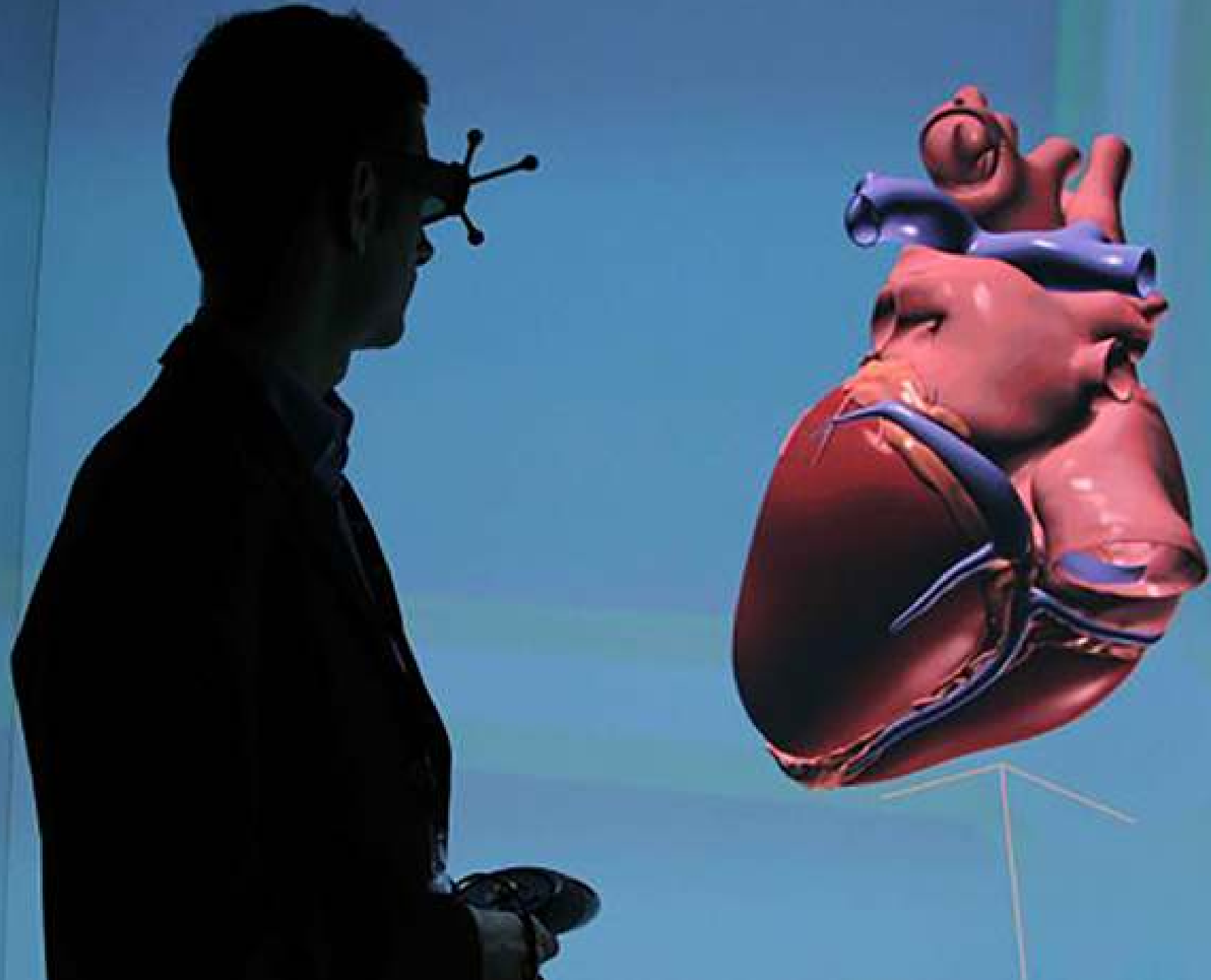






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# Course audience

- **Computer Science students** learning Computer Graphics, Physics or Machine Learning 
  - and who are afraid to ask "what's a GPU?", "what's a shader?"
- **Web designers** wishing to add 3D graphics to their sites 
- **Game developers** wishing to conquer the Web 
- Anyone looking for a **simple introduction to 3D**
  - and who has no clue where to start 

➡ Feel free to skim through technical sections and use this course as future reference

# Course prerequisites

We'll start from scratch but these should help:

- **Math** 
  - 3D vectors and [matrices](#)
- **Programming** 
  - **JavaScript** [notions](#), or any similar language (HTML kept minimal)
- **3D API** 
  - [OpenGL](#), DirectX, Metal
- 3D Software (Blender, Unity, Unreal Engine, Godot Engine)
- Desktop / Laptop + [VSCode](#)

# Course contents

- **Demo** 
  - Existing **3D Web Apps**
- **Theory** 
  - A brief **history** of 3D on the Web
  - **Concepts**: Architecture, Pipeline, APIs
- **Practice** 
  - 3D Web **Programming**
    - **WebGL, THREE.js**
    - Other APIs



# Planning

- **Day 1** (6 hours)

-  **Theory**
-  **WebGL exercises**
-  **Lunch**
-  **THREE.js Theory + full exercise**
-  **Explore examples + choose a personal **project****

- **Day 2** (6 hours)

-  **Evaluation: Quizz** 20 questions / ~20 min ➡ 20 points max
-  **Personal project / game jam** ➡ +5 bonus points!

# Project evaluation

- ★ Project can be finished at home 🏠
- 👤 1 person per project
- 🐙 send git repo link by mail (invite if private) with:
  - README
  - LICENSE
  - illustration (image / GIF / mp4)
  - link for live testing
  - source code

# Project evaluation criteria

- originality 🧐
- interactions 🙌
- physics 💥 / animations 🏃 / sounds 🎵 / eye-candy 🌟
- GIS 🌍
- code quality ✨, tricks 😊, performance ⌚
- fun 🎉

# Project grading

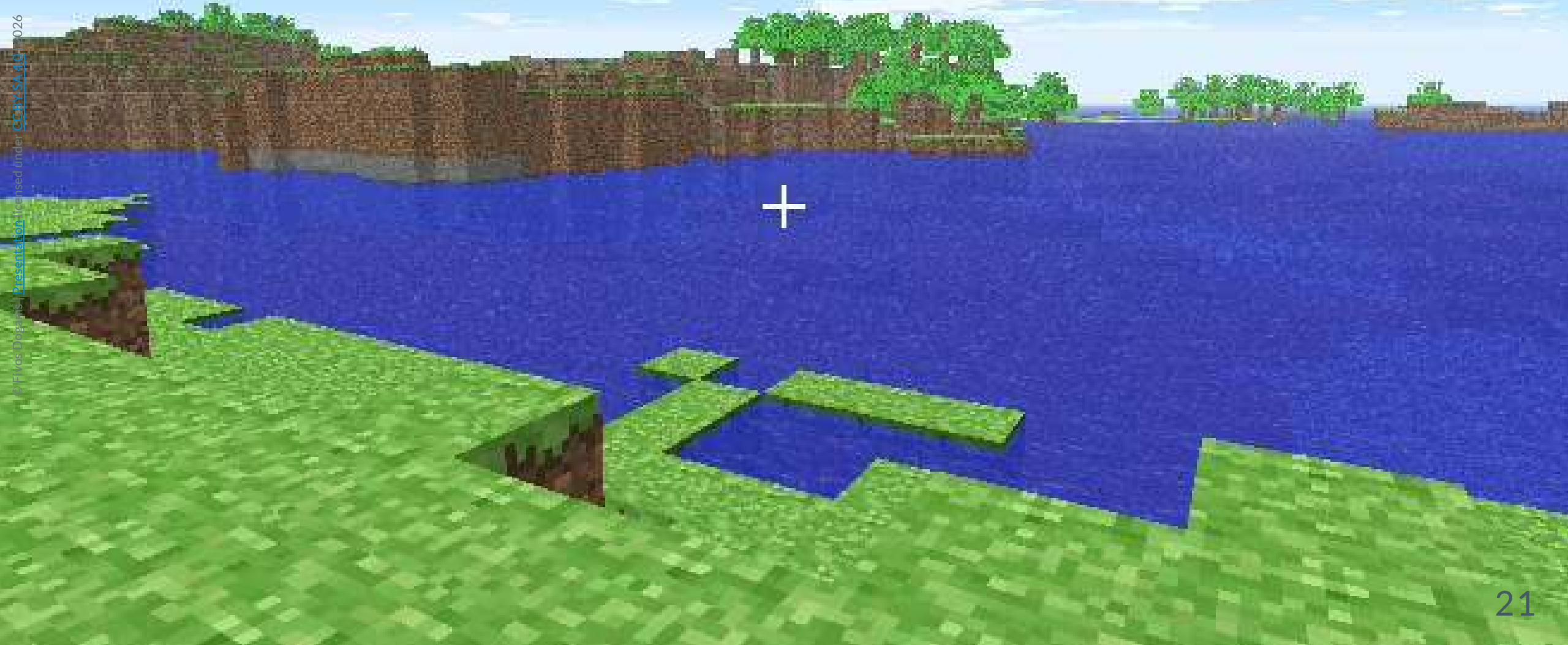
- up to **5** bonus points
- choose features from previous slide
- for each implemented **feature**:
  - not done: **0 pt** 🤔 zzz
  - nice try / buggy: **0.5 pt** 🙄 🐛
  - basic / good enough: **1 pt** 😐
  - great / polished: **1.5 pts** 😊
  - impressive: **2 pts** 🤠 ★



# 3D Web Apps

- Games
- e-Commerce
- 3D content creation
- 3D data exploration
- Interactive art

# Minecraft Classic



# Aviator

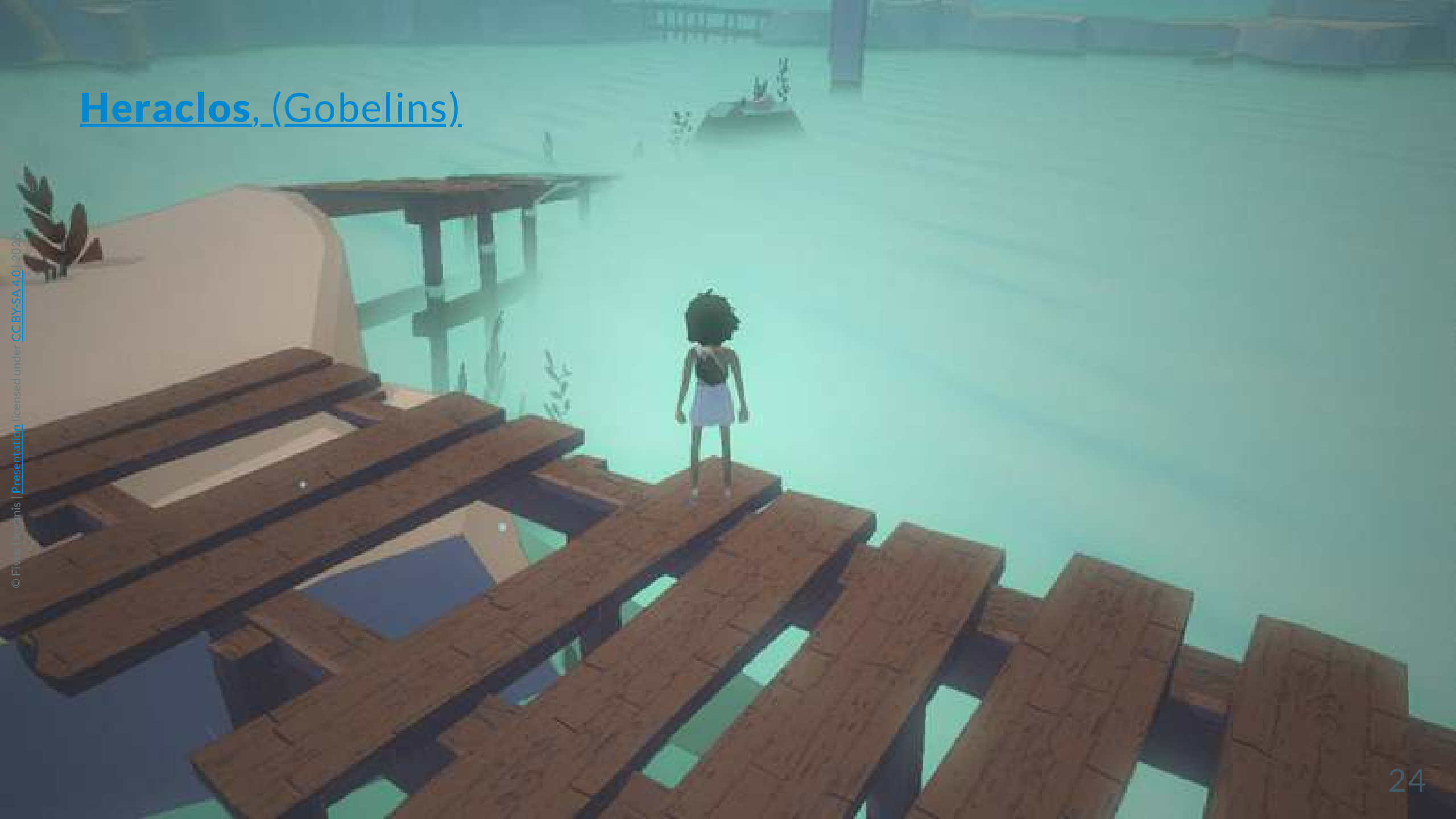
## Aviator 2



## Blob Opera (Google).



## Heraclos,\_(Gobelins).



## Coastal World (Making Of)



# Messenger



# THREE Quake



## Google Pixel 10 Pro Fold



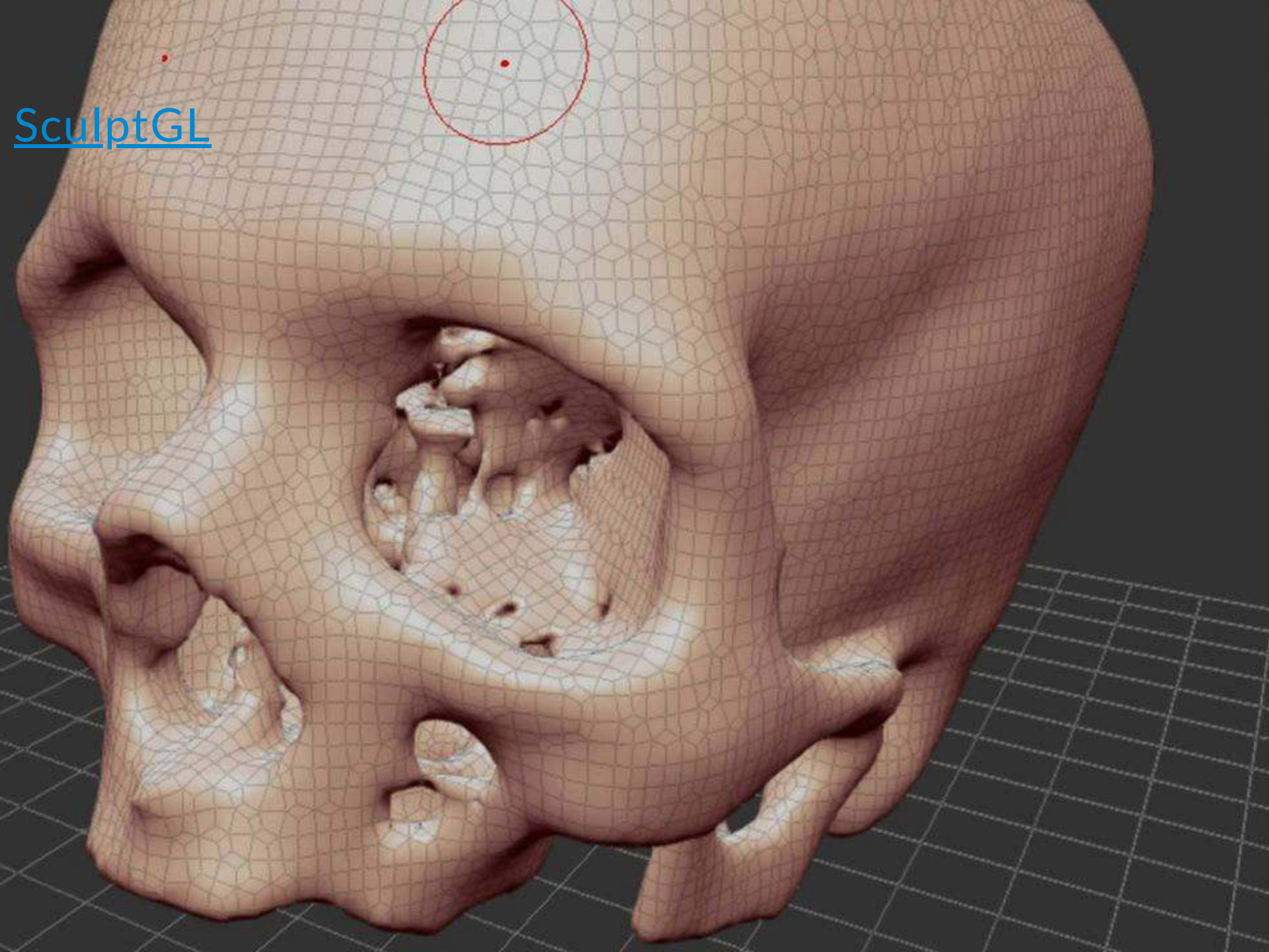
BMW



# OUIGO (Making Of)



# SculptGL



▶ RENDERING

▶ TOPOLOGY

▼ SCULPTING & PAINTING

Tool

Tool Smooth (-Shift)

Radius (-X)

Intensity (-C)

Relax only

Thin surface (front vertex only)

Alpha

Lock position

Texture None

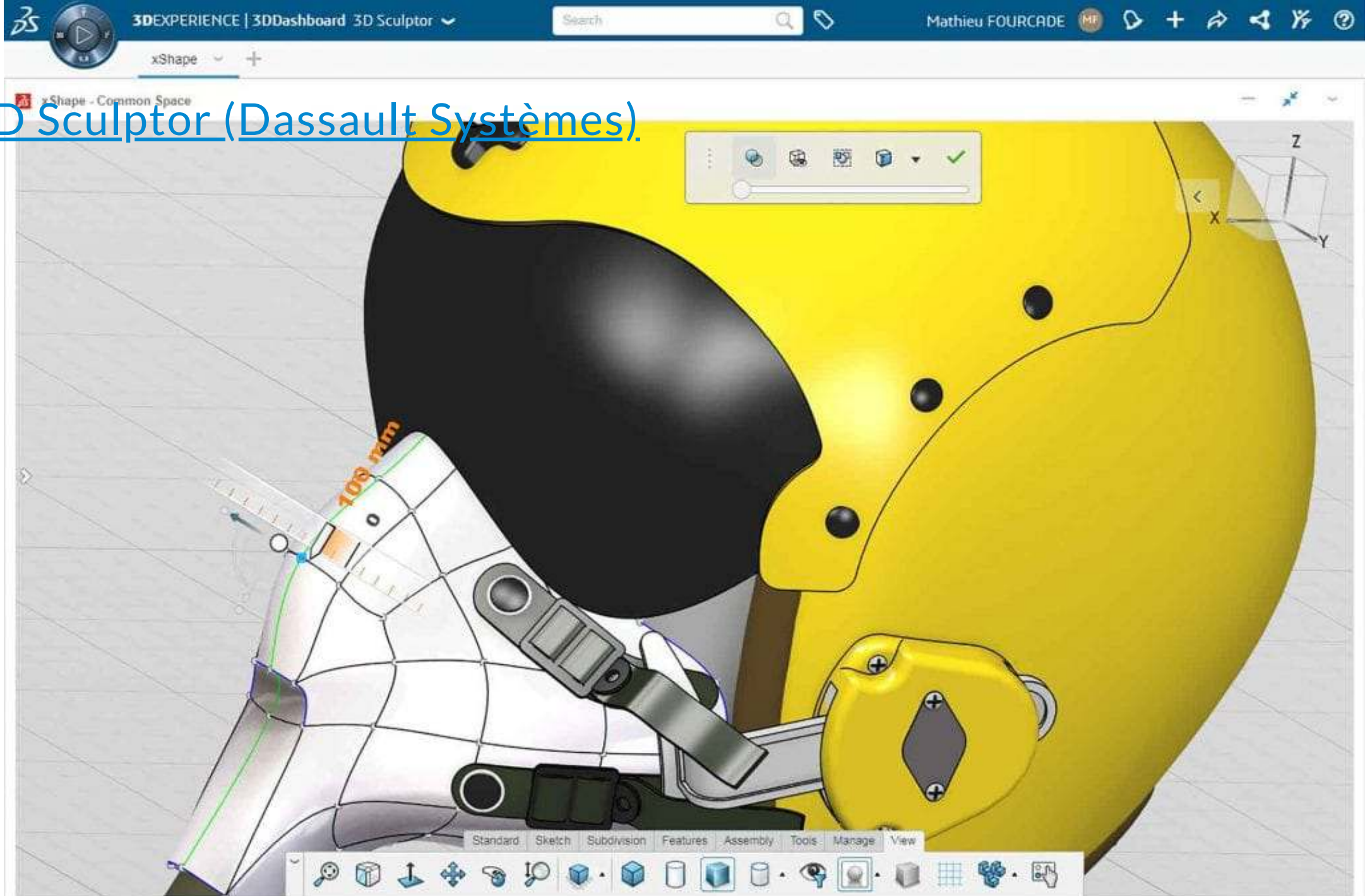
Import alpha tex (jpg, png)

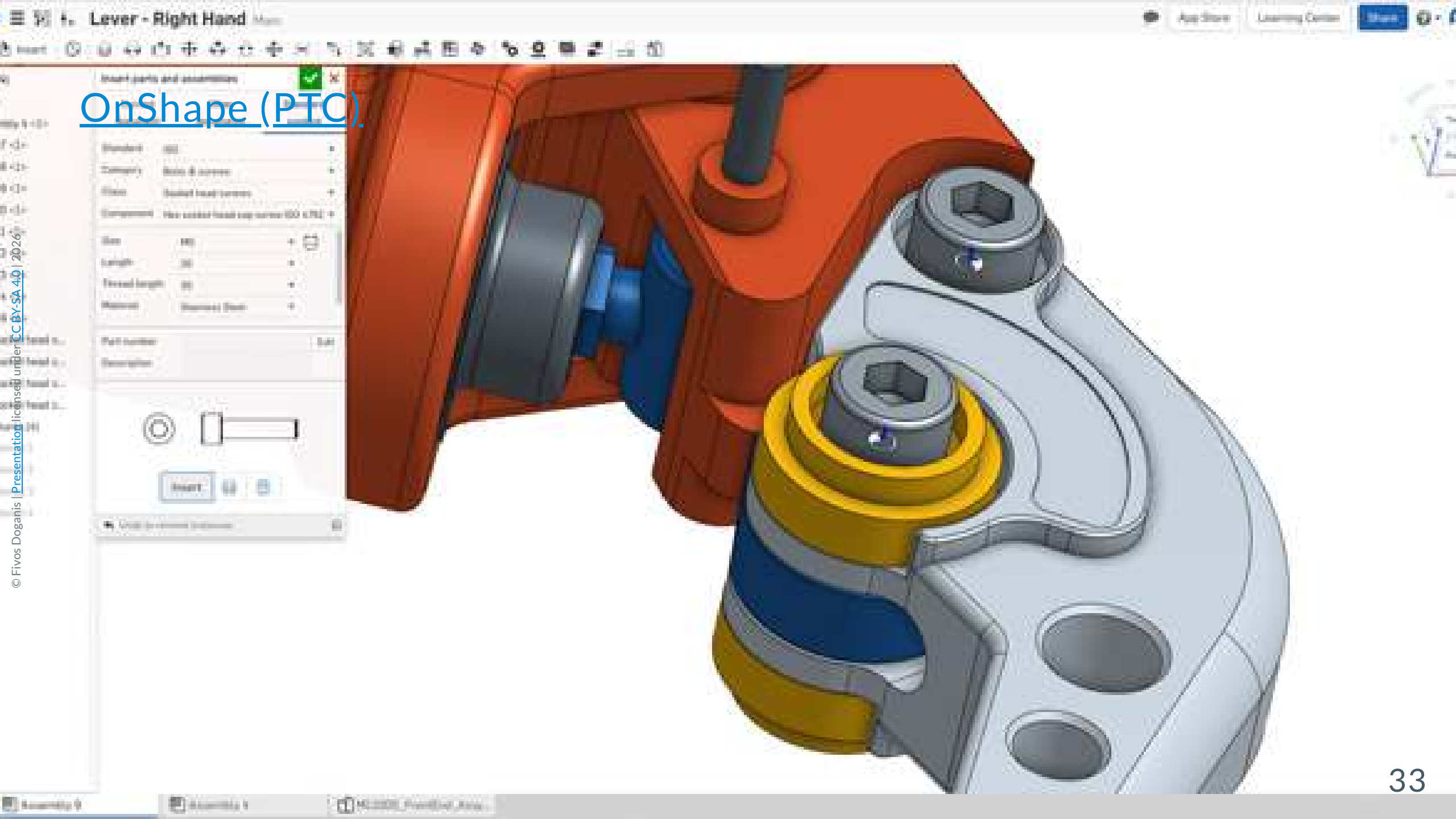
Common

Symmetry

Continuous

## 3D Sculptor (Dassault Systèmes)





# OnShape (PTC)

# SketchFab (Epic)

## The place to be for 3D

Publish and find the best 3D content. Easy and free.

[JOIN FOR FREE](#)


Uppleurodot Feroc Swim Cycle  
by Kyam01



Free unlimited uploads



Universal 3D viewer



Embed anywhere



Download



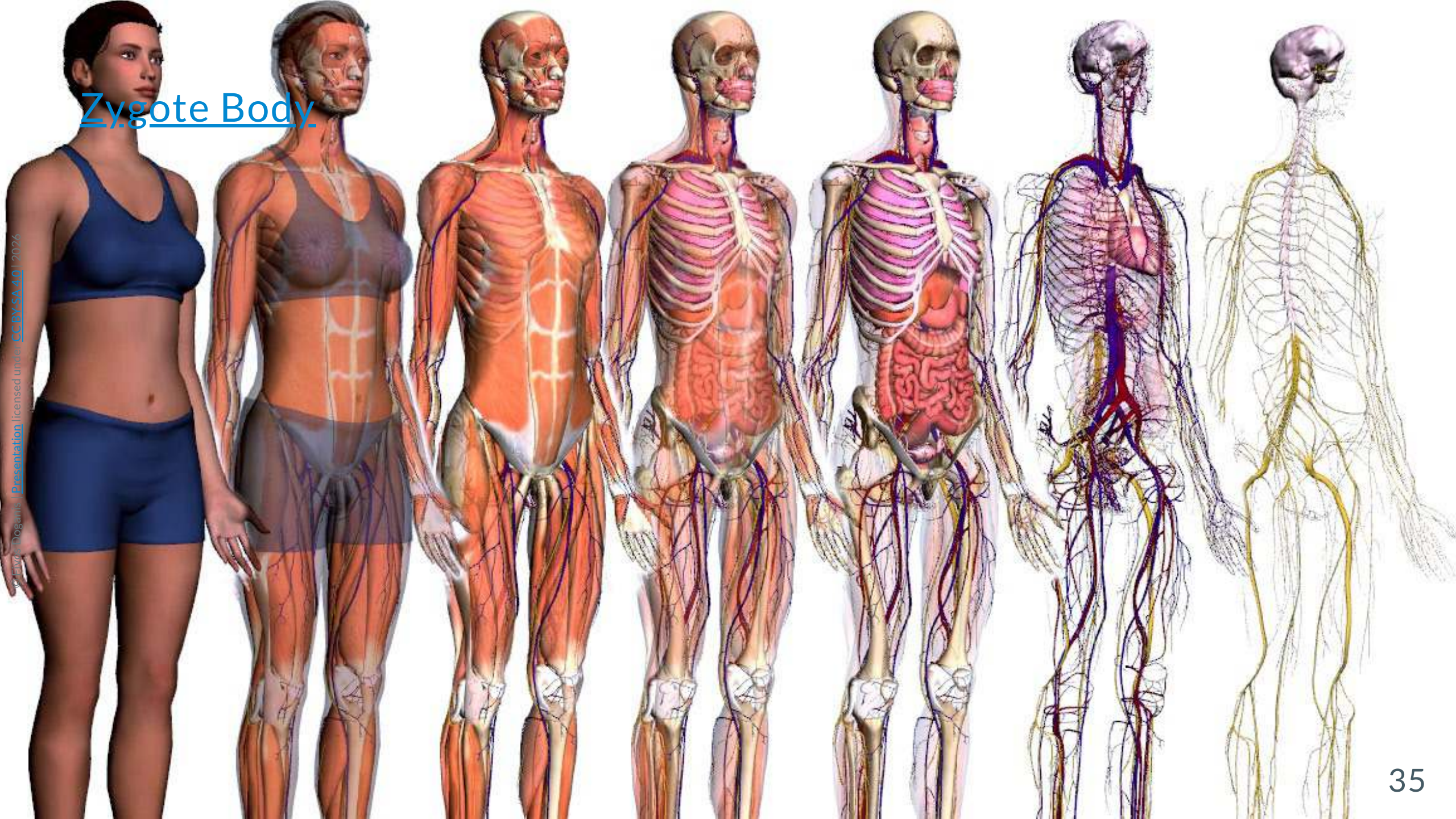
AR & VR ready

[SEE MORE COOL FEATURES](#)

## Explore more than 700,000 models

[STAFFPICKS](#)
[POPULAR](#)
[DOWNLOADABLE](#)
[BRANDS](#)
[3D SCANS](#)
[3D PRINTABLE](#)
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[ARCHITECTURE](#)
[CHARACTERS](#)
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[MISCELLANEOUS](#)
[OBJECTS](#)
[SCENES](#)
[SCIENCE](#)
[VEGETAL](#)
[VEHICLES](#)

# Zygote Body



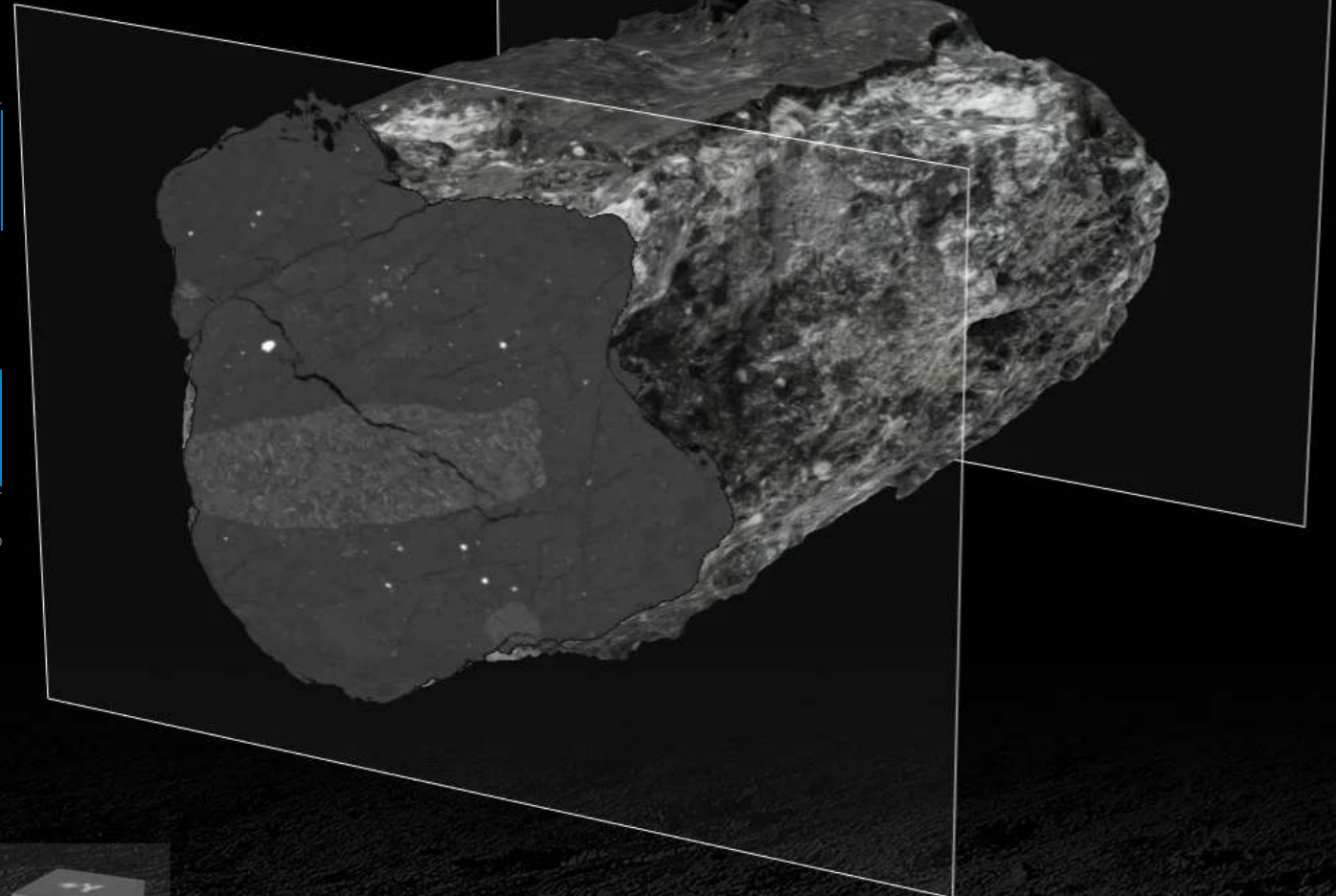
Z-Anatomy



Z-ANATOMY

**THE NEW  
OPEN SOURCE  
3D ATLAS  
OF ANATOMY**

NASA



Sample **60639,0** ✕

Collection Apollo Lunar Collection

Origin Moon

Collected Descartes Highlands, Station 10, Apollo 16

Classification Regolith Breccia

## Micro X-Ray Computed Tomography

Cut into the rock from three different orientations to reveal X-Ray CT imagery of the rock's interior.

### Slice Orientation and Position

Use your mouse to drag the sliders below. Release the mouse for full resolution imagery.

X  5.560 cm

Y  4.113 cm

Z  5.363 cm

### Details

Make fine selection changes with + and open high resolution slice imagery.

|   | View XCT<br>Planes | XCT Slice<br>Number | View<br>Slice | XCT Slice<br>Number | View<br>Slice |
|---|--------------------|---------------------|---------------|---------------------|---------------|
| X |                    | - 1423 +            |               | - 0000 +            |               |
| Y |                    | - 0000 +            |               | - 1053 +            |               |
| Z |                    | - 0548 +            |               | - 1921 +            |               |

Download the unprocessed 16-bit XY XCT TIFFs

# iTowns (IGN)



# THREE Geospatial - Clouds



# [The Cursed Library](#)



# History

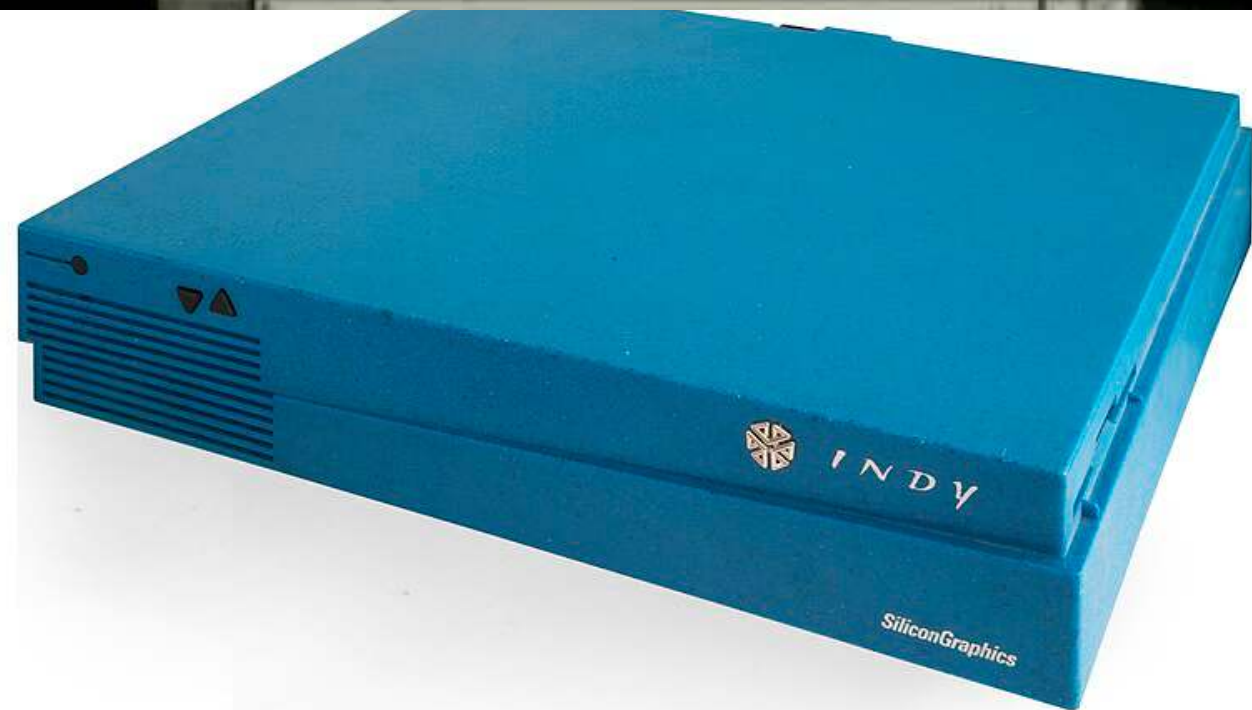
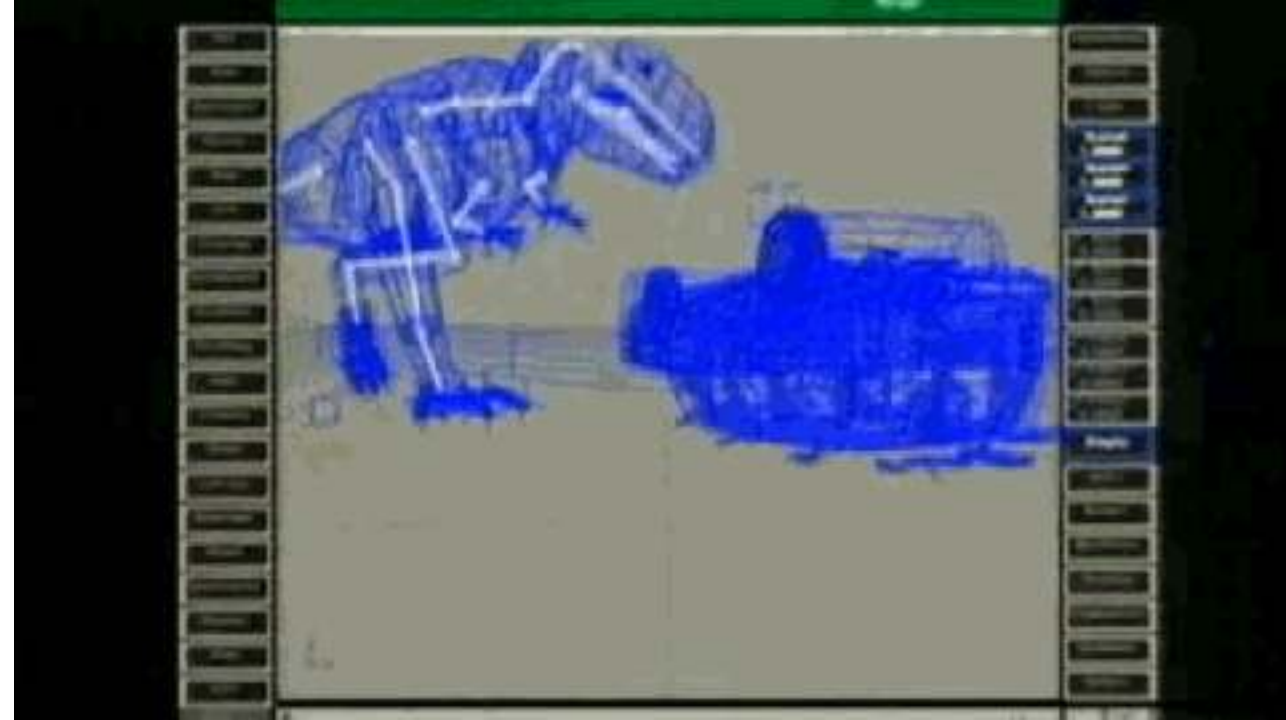
The past, present and future of Web 3D

*"Dis Papy, c'était comment la 3D avant?"*

# Prehistory

## (1983 - 1993)

- Silicon Graphics (SGI) hardware only
  - IRIX OS
- IRIS GL (1983)
  - API **close to hardware**
- IRIS Inventor (1988)
- **OpenGL 1.0** (1993)
  - Open API, Multi-OS



# Fixed Pipeline (1993 - 2004)

- 3dfx **Glide** API (1996)
  - Voodoo: "hardware 3D acceleration" for all
- Microsoft **Direct X** API (1997)
  - Windows-only 😞
- **OpenGL ES** (2004)
  - **Subset** for "Embedded Systems" 📱 🎮
  - "most widely deployed 3D graphics API"
- **OpenGL 2.0** (2004)
  - GLSL Shaders 🎨





- Foundation of **nVIDIA** (1993)
- NV1 in **SEGA Saturn** (1994)
- GeForce 256 (1999)
  - democratizes the **GPU**:  
**G**raphics **P**rocessing  
**U**nit, Transform &  
Ligthing
- GeForce 3 (2001): NV2A in Microsoft's **Xbox**,  
**programmable shading**



# Other players

- **SGI + Nintendo: Project Reality / N64 (1996)**
  - SGI ends in 2006 💀
- **Imagination Technologies (PowerVR GPU) + Sega: Dreamcast (1998)**
- [Intel i740](#) (1998) : OS in 3D
- **ATI (AMD) + Nintendo: Gamecube (2001)**



# Shaders, Mobile, Web (2004+)

- OpenGL ES 2.0 (2007)
  - **Mobile subset with shaders**
- Canvas 3D (2007), **WebGL** ancestor
  - created by [Vladimir Vukićević](#) at Mozilla
- **WebGL 1.0 (2011)** ★ 🎉
  - OpenGL ES 2.0 functionality for the Web!
- OpenGL ES 3.0 (2012), **3.1 (2014): not for Apple** 😞
- **WebGL 2.0 (2017)**
  - OpenGL ES 3.0 exposed to the Web



“ **Before WebGL**, you couldn't really do 3D on the web at all.

There was **powerful 3D hardware** everywhere on both desktops and mobile phones, but **the web couldn't tap into any of it**.

There were some **plugins**, but users had to do an extra **installation step** that was a huge obstacle to adoption.

All the browser vendors knew that this was a **challenge** that needed to be resolved, which is why we came together as a **Khronos** Working Group.

”



# WebGL Stack

Content downloaded  
from the Web

Middleware provides accessibility  
for non-expert programmers  
E.g. three.js library

Content  
JavaScript, HTML, CSS, ...

JavaScript Middleware  
three.js  babylon.JS  
 PLAYCANVAS

Low-level WebGL API provides a  
powerful foundation for a rich  
JavaScript middleware  
ecosystem

Browser provides WebGL  
3D engine alongside other HTML5  
technologies - no plug-in required

WebGL

CSS

JavaScript

HTML5



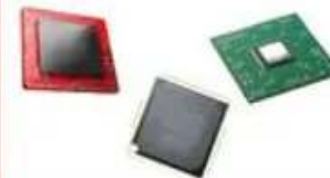
Reliable WebGL  
relies on work by  
both GPU and  
Browser Vendors  
->

OS Provided Drivers  
WebGL uses native OpenGL or  
OpenGL ES or  
Angle = OpenGL ES over DX9/11



OpenGL|ES

OpenGL



Khronos has the  
right membership  
to enable that  
cooperation

# WebGL architecture: software stack

- **Code:** HTML + CSS + JS
  - JS code inside the web page makes WebGL API calls
- **Browser:**
  - browser interprets JS code (using JS Engine)
  - turns WebGL calls into OpenGL calls (binding)
- **OS + Driver:** converts OpenGL calls to
  - DirectX calls on Windows, Metal on Apple (using [ANGLE](#))
  - OpenGL or OpenGL ES calls on other OSes
- **CPU + GPU:** run the **hardware accelerated** code!

# Binding example: from JS to C++

```
gl.drawElements(primitiveType, count, indexType, offset);
```

```
JSValue JSCanvasRenderingContext3D::glDrawElements(JSC::ExecState* exec, JSC::ArgList const& args)
{
    unsigned mode = args.at(0).toInt32(exec);
    unsigned type = args.at(1).toInt32(exec);

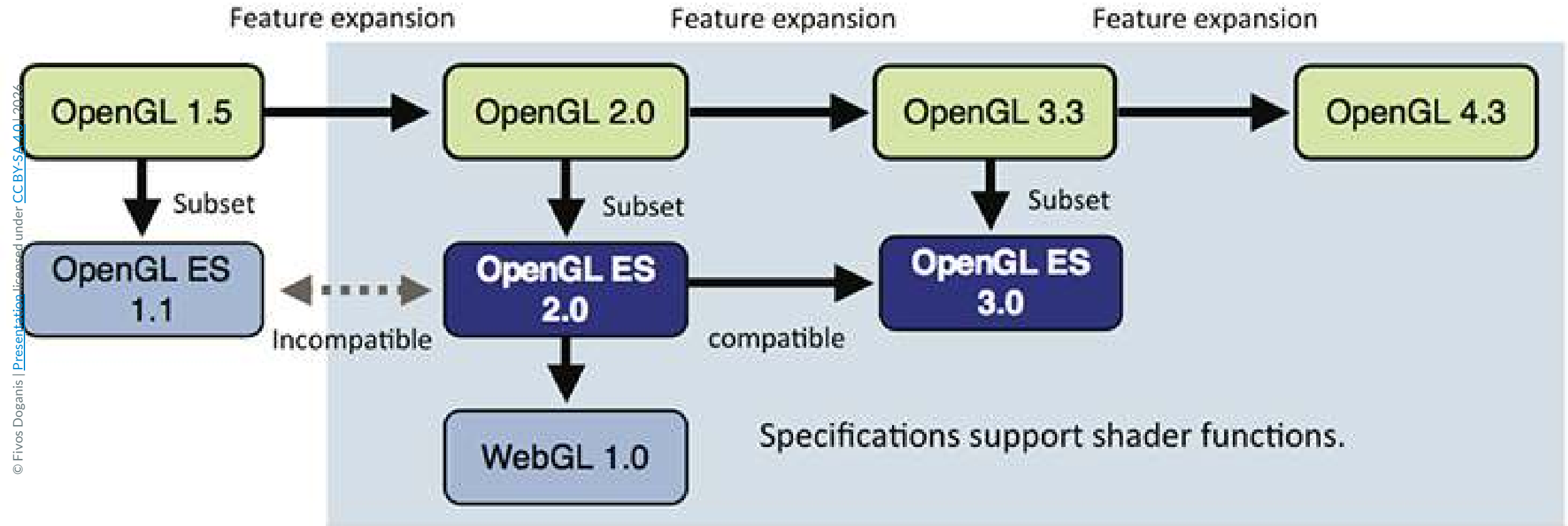
    unsigned int count = 0;

    // If the third param is not an object, it is a number, which is the count.
    // In this case if there is a 4th param, it is the offset. If there is no
    // 4th param, the offset is 0
    if (!args.at(2).isObject()) {
        count = args.at(2).toInt32(exec);
        unsigned int offset = (args.size() > 3) ? args.at(3).toInt32(exec) : 0;
        impl()->glDrawElements(mode, count, type, (void*) offset);
    } else {
```

# Impact of stack on performance

- Interpreted JS code is ~10x slower than native code
  - unless you use [WebAssembly](#) ("only" 2x slower than native)
- On mobile devices, native code is ~10x slower than on desktop
- **Performance tips**
  - reduce processing in JS code, let the shaders do the hard work
  - once shaders are **compiled** and rendering data is on the GPU, the code runs at near **native speeds**
  - GPU memory is limited: use [Draco](#) geometry compression, and [Basis](#) GPU texture compression

# Evolution



# WebGL's Evolution

## Pervasive OpenGL ES 2.0

OpenGL and OpenGL ES ships on every desktop and mobile OS.  
3D on the Web is enabled!

### Mobile Graphics

Programmable Vertex and Fragment shaders



2007

OpenGL ES 2.0

## Desktop Graphics

Textures: NPOT, 3D, Depth, Arrays, Int/float

Objects: Query, Sync, Samplers

Seamless Cubemaps, Integer vertex attributes

Multiple Render Targets, Instanced rendering

Transform feedback, Uniform blocks

Vertex array objects, GLSL ES 3.0 shaders



2012

OpenGL ES 3.0

Apple does not ship

OpenGL ES 3.1

Cannot bring compute shaders into core WebGL

Compute Shaders



2014

OpenGL ES 3.1

## After WebGL 2.0?

W3C is working on WebGPU  
Layering over Vulkan/DX12/Metal

Possibly leveraging SPIR-V IR

<https://www.w3.org/community/gpu/>



4 years

2011  
WebGL 1.0

5 years

2017  
WebGL 2.0

Work in Progress  
Compute Context  
Multiview extension

Conformance Testing is vital for Cross-Platform Reliability

WebGL 2.0 conformance tests are very thorough 10x more tests than WebGL 1.0 tests



**The end of an  
API?**

# Next Generation OpenGL Initiative

- Ground up re-design of API for high-efficiency access to graphics and compute on modern GPUs and platforms
- Design from first principles - even if means breaking compatibility with traditional OpenGL
- An open-standard, cross-platform 3D+compute API for the modern era

Platform Diversity and  
need for cross-platform  
API standards *increasing*



After twenty two years - the architecture of  
GPUs and platforms has radically changed

# Evolution issues

- New hardware, new needs since 1993
  - **mobiles**, wearables   
  - **embedded systems**, AI, Vision  
- API has become more and more **complex**
  - coding fast and bug-free **drivers** is hard
  - OpenGL **extensions** are not universal
  - API **subset** needed to deprecate old and slow APIs
-  New API needed, and it should be
  - **low-level, universal, fast and abstract**

# But do we really need a new API?

- Not really, see **AZDO**: Approaching Zero Driver Overhead (2016)
  - using the "right" OpenGL subset and the "right" extensions, we can squeeze as much performance as possible from the GPU
    - <https://fr.slideshare.net/CassEveritt/approaching-zero-driver-overhead>
    - <https://fr.slideshare.net/tlorach/opengl-nvidia-commandlistapproaching-zerodriveroverhead>
  - main idea
    - free the CPU ➡ fewer DrawCalls
    - keep the GPU busy ➡ send more data at once

# Challenge of Issuing Commands

Issuing drawcalls and state changes can be a real bottleneck



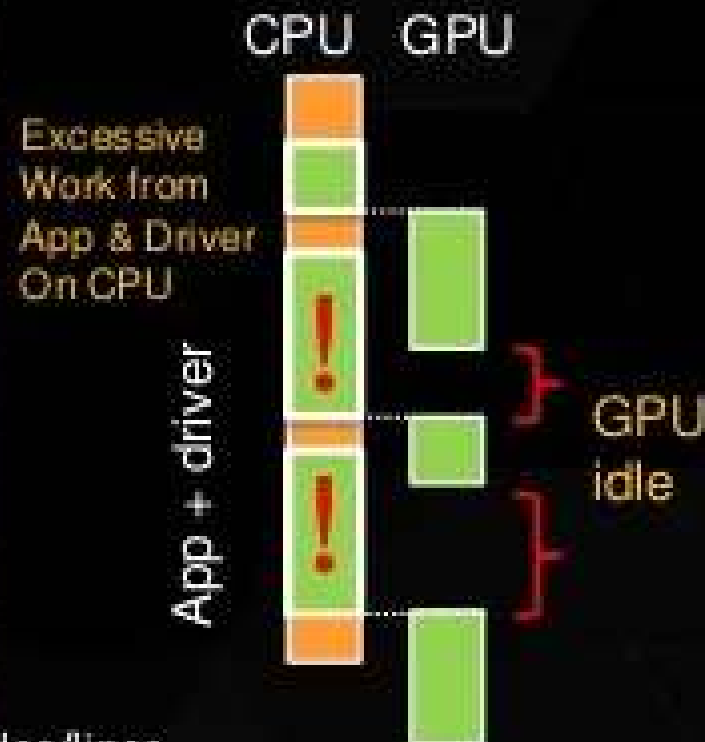
- 650,000 Triangles
- 68,000 Parts
- ~ 10 Triangles per part



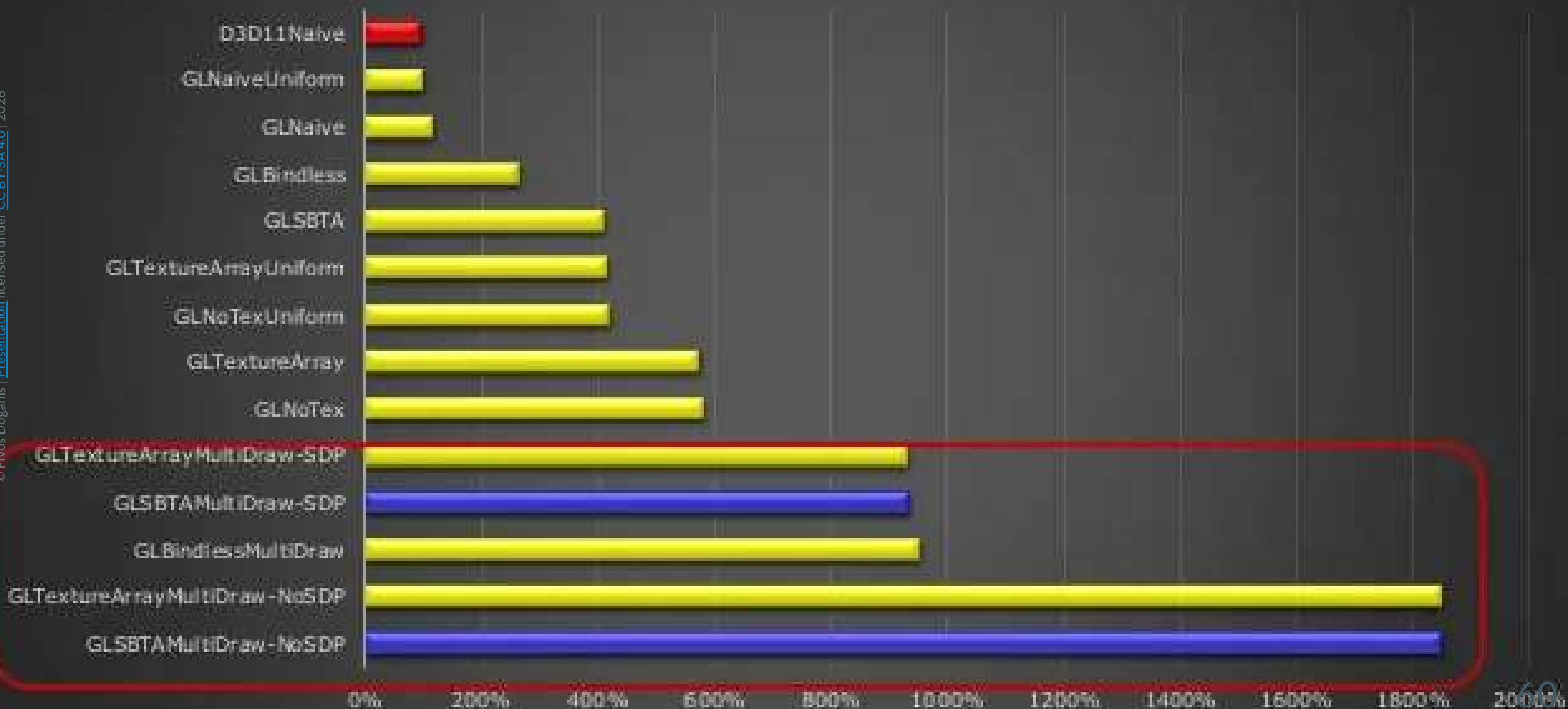
- 3,700,000 Triangles
- 98 000 Parts
- ~ 37 Triangles per part



- 14,338,275 Triangles/lines
- 300,528 drawcalls (parts)
- ~ 48 Triangles per part



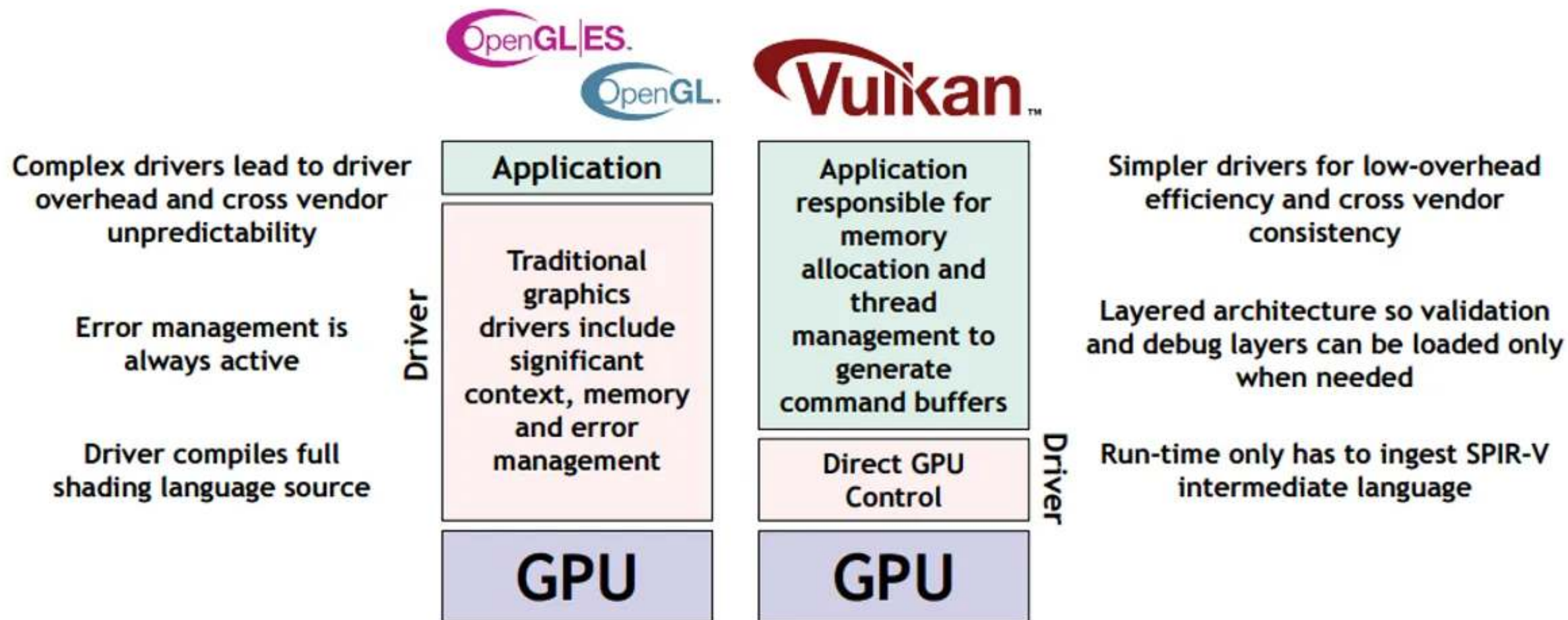
## TexturedQuads – Normalized Obj/s



# API Fragmentation

- Proprietary API proliferation ➡ no portability 😞
  - close to the GPU ➡ fast
  - new ➡ "clean"
- **Direct X 12** (Microsoft) : Windows, Xbox
- **Mantle** (AMD) transferred to **Khronos** to become **Vulkan**
  - **new open low-level standard** ★
- **Metal** (Apple)
  - looks like Vulkan, Metal was created first

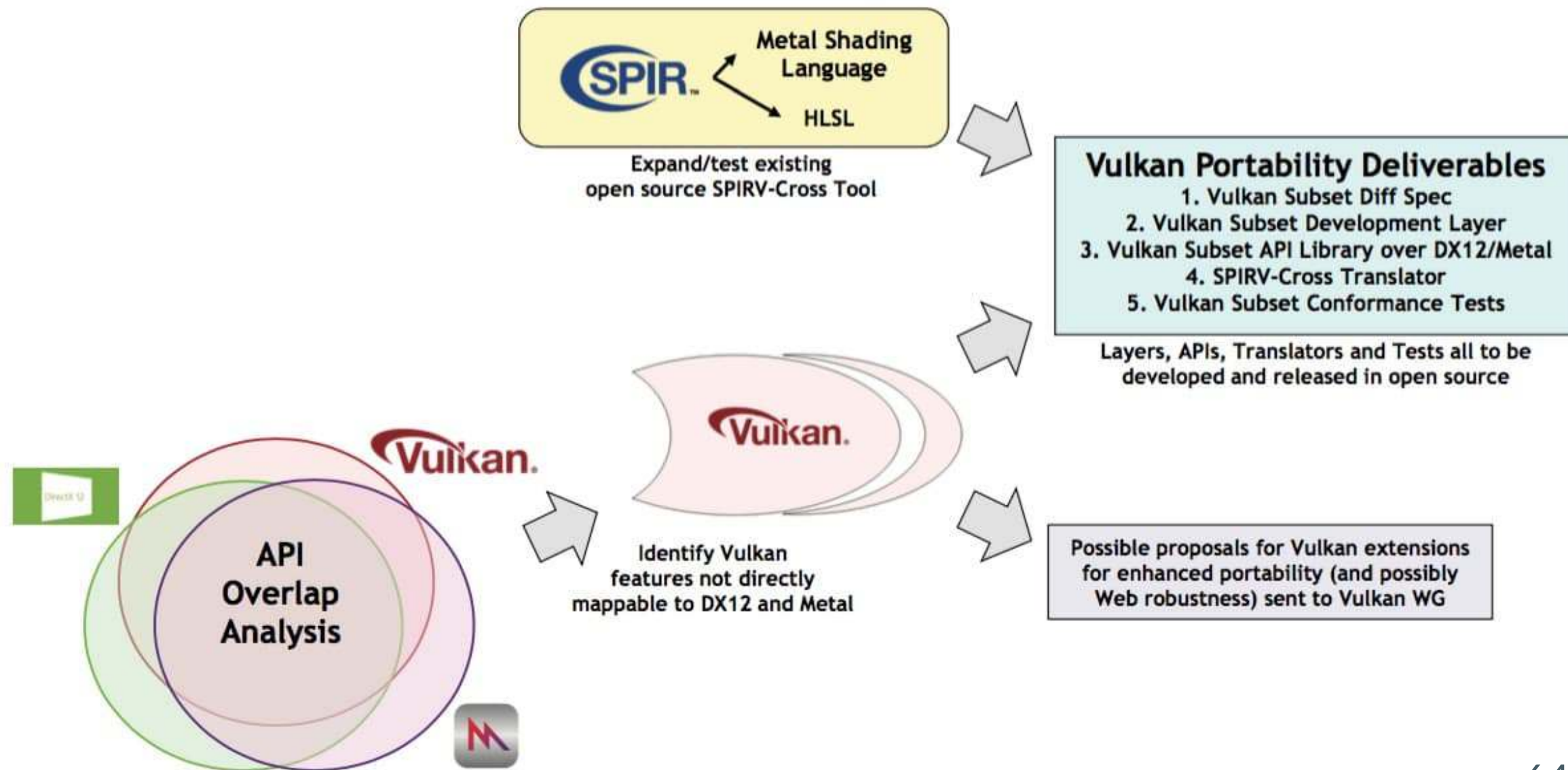
# Vulkan Explicit GPU Control



# Can we reunite all these new APIs?

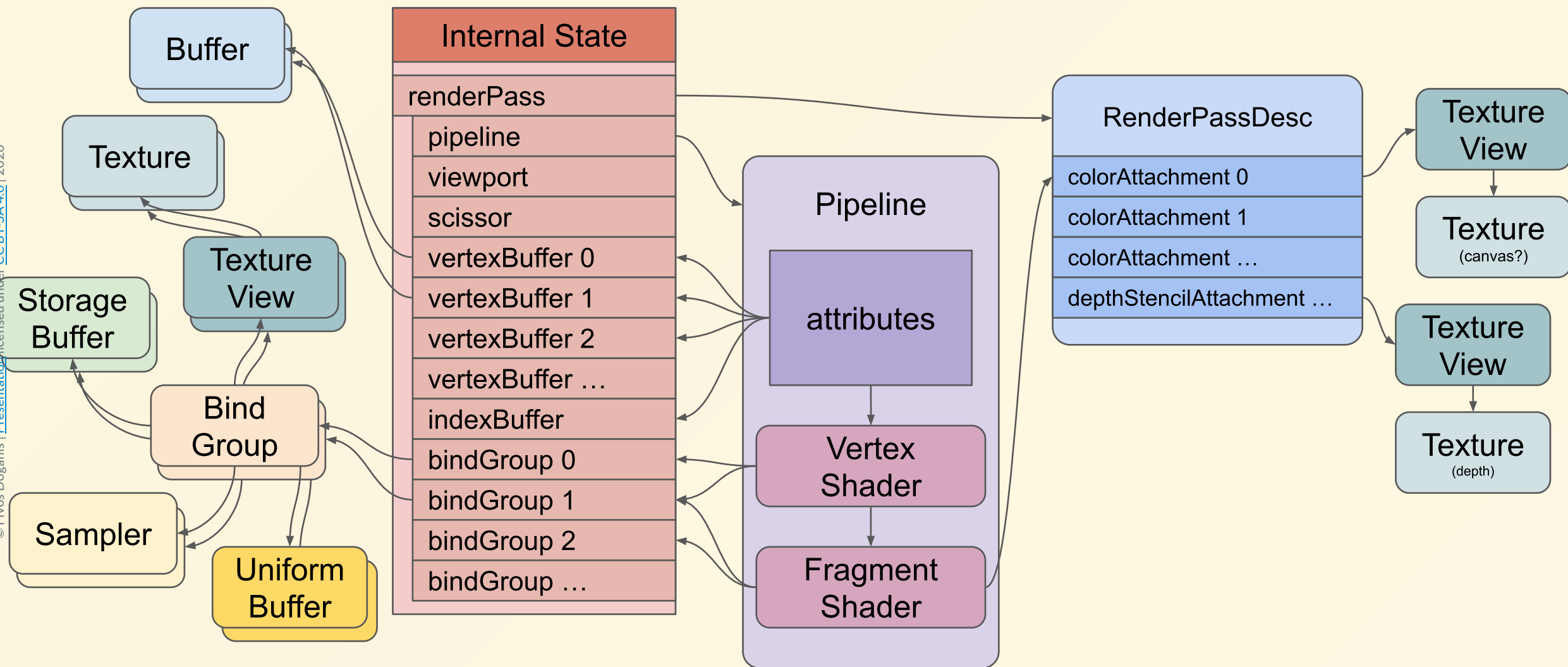
Which common subset to use?

# Vulkan Portability TSG Process



# WebGL Next == WebGPU ?

- Apple's "WebMetal", API similar to Metal
- API partially reused and renamed **WebGPU**
  - [API still being defined](#)
  - both **low-level** and **object-oriented** (no global state!)
  - **fast**
  - subset for **web AND native**, despite the "web" in the name
    - a bit like "Vulkan ES" / "Metal ES"
- Can replace WebCL (Compute Shaders), abandonned 😞
- Compatible with [WebAssembly](#)



**All this is so confusing, which API  
should I actually use !?**

Well...

- “ We hope for **universal availability of WebGL 2.0 soon**. If you need to ship your product **today, WebGL 2.0 is the way to go**. WebGL will be **supported indefinitely**. You do not need to worry about it going away. ”
- “ **WebGPU**'s timeline is discussed in the answer to the previous question. WebXR and WebAR are already working on WebGPU integration. ”

[Khronos WebGL meetup](#), November 18, 2020

“ **WebGL 2.0** can now be considered **universally available** across browsers, operating systems and devices.

As an application author, you can **target WebGL 2.0 with confidence.**

We encourage you to **migrate to WebGL 2.0**

It's no longer necessary to maintain a WebGL 1.0 fallback path unless you need to reach absolutely every device.

In particular, **older Windows machines and Android devices.** ”

“ **WebGPU** standardization continues; conformance testing in high gear

Aiming to reach 1.0 in 2022 Q2 (spec and conformance tests). ”

# WebGPU

- “ A "modern" graphics API for the Web:  
**A successor to WebGL, not a replacement.**  
Compute shaders on the Web!  
Lower overhead API  
Foundation for future features  
(bindless, ray tracing, multithreading ...) ”
- “ [webgpu.h](https://webgpu.h)  
C API for WebGPU — analogous to OpenGL ES vs WebGL ”

[Khronos WebGL + WebGPU meetup](#), March 19 2025

# WebGL - 3D Canvas graphics

Method of generating dynamic 3D graphics using JavaScript, accelerated through hardware

| IE | Edge | Firefox | Chrome | Safari | iOS Safari | Opera Mini | Chrome for Android | Android Browser | Samsung Internet |
|----|------|---------|--------|--------|------------|------------|--------------------|-----------------|------------------|
| 9  | 142  | 145     | 142    | 26.0   | 26.0       |            |                    | 4.4             | 27               |
| 10 | 143  | 146     | 143    | 26.1   | 26.1       |            |                    | 4.4.4           | 28               |
| 11 | 144  | 147     | 144    | 26.2   | 26.2       | all        | 144                | 144             | 29               |
|    |      | 148     | 145    | 26.3   | 26.3       |            |                    |                 |                  |

✓ ✗ Partial Support

Global: 96.75% + 0% = 96.75%

# WebGL 1.0

- available to **99,87%** of browsers tracked by [caniuse](https://caniuse.com/)!
  - latest data: <https://caniuse.com/webgl>
- including **mobile** browsers
  - Chrome for Android
  - iOS Safari

 **available everywhere!** 

# WebGL 2.0

Next version of WebGL. Based on OpenGL ES 3.0.

| IE | Edge | Firefox | Chrome | Safari | iOS Safari | Opera Mini | Chrome for Android | Android Browser | Samsung Internet |
|----|------|---------|--------|--------|------------|------------|--------------------|-----------------|------------------|
| 9  | 142  | 145     | 142    | 26.0   | 26.0       |            |                    | 4.4             | 27               |
| 10 | 143  | 146     | 143    | 26.1   | 26.1       |            |                    | 4.4.4           | 28               |
| 11 | 144  | 147     | 144    | 26.2   | 26.2       | all        | 144                | 144             | 29               |
|    |      | 148     | 145    | 26.3   | 26.3       |            |                    |                 |                  |

✓ ✗ Partial Support

Global: 95.79% + 0% = 95.79%

# WebGL 2.0

- available to **98.79%** of users!
  - latest data: <https://caniuse.com/webgl2>
- Standard at Apple since iOS 15! (september 2021) 🎉

➡ **official, [you can start coding with it!](#)** (check [availability](#))

- retrocompatibility: WebGL 1.0 works in a WebGL 2.0 context
- WebGL 1.0 [polyfill](#) to support a subset of WebGL 2.0 (  shaders)
- you should learn WebGL 1 to understand existing code.

# WebGL 2.0 on iOS

➡ Test WebGL 2 support here:

- <https://webglreport.com/?v=2>
- <https://get.webgl.org/webgl2/>

# WebGL 2.0 : standardized extensions

Depth Textures (WEBGL\_depth\_texture)  
Floating Point Textures (OES\_texture\_float/OES\_texture\_float\_linear)  
Half Floating Point Textures (OES\_texture\_half\_float/OES\_texture\_half\_float\_linear)  
Vertex Array Objects (OES\_vertex\_array\_object)  
Standard Derivatives (OES\_standard\_derivatives)  
Instanced Drawing (ANGLE\_instanced\_arrays)  
UNSIGNED\_INT indices (OES\_element\_index\_uint)  
Setting gl\_FragDepth (EXT\_frag\_depth)  
Blend Equation MIN/MAX (EXT\_blend\_minmax)  
Direct texture LOD access (EXT\_shader\_texture\_lod)  
Multiple Draw Buffers (WEBGL\_draw\_buffers)  
Texture access in vertex shaders

➡ when WebGL 2.0 is not supported, we can get close to it using  
WebGL 1.0 + **these extensions!**

# WebGL 1.0.1

WebGL 1.0.1 == WebGL 1.0 + omnipresent extensions

```
ANGLE_instanced_arrays  
EXT_blend_minmax  
OES_element_index_uint  
OES_standard_derivatives  
OES_vertex_array_object // use it!  
WEBGL_debug_renderer_info  
WEBGL_lose_context
```

 **always available, use them!**

# WebGL 1.0.2

WebGL 1.0.2 == WebGL 1.0.1 + [omnipresent extensions \(since 2021\)](#).

```
EXT_texture_filter_anisotropic  
OES_texture_float  
OES_texture_float_linear  
OES_texture_half_float  
OES_texture_half_float_linear  
WEBGL_depth_texture
```

 **always available, use them!**

# WebGL 1.0.3 ⚠️

WebGL 1.0.3 == WebGL 1.0.2 + [omnipresent extensions \(since 2022\)](#):

```
EXT_shader_texture_lod  
EXT_sRGB  
EXT_frag_depth
```

- but [one very useful extension](#) is not supported on Android 😞

```
WEBGL_draw_buffers
```

➡️ **check availability before use**

# WebGL 2.0 extensions

WebGL 2.0 [omnipresent extensions since 2022](#):

```
EXT_texture_filter_anisotropic  
OES_texture_float_linear  
WEBGL_debug_renderer_info  
WEBGL_lose_context
```

- but one fails on [Safari](#)  ([EXT float blend](#) ?): problem for **GPGPU**

```
EXT_color_buffer_float
```

 **check availability before use**

# Available != no bugs

“ **#WebGL2** is a rubbish job on **#IOS14**. On Ipad pro more than half of the conformance tests fail ( 153553 over 260803 - tested here: <https://khronos.org/registry/webgl/sdk/tests/webgl-conformance-tests.html>). For GPGPU I still use WebGL1 for IOS devices. ”

[@xavierbourry, July 2020](#)

# WebGPU

An API for complex rendering and compute, using hardware acceleration. Use cases include demanding 3D games and acceleration of scientific calculations. Meant to supersede WebGL.

| IE | Edge | Firefox | Chrome | Safari | iOS Safari | Opera Mini | Chrome for Android | Android Browser | Samsung Internet |
|----|------|---------|--------|--------|------------|------------|--------------------|-----------------|------------------|
| 9  | 142  | 145     | 142    | 26.0   | 26.0       |            |                    | 4.4             | 27               |
| 10 | 143  | 146     | 143    | 26.1   | 26.1       |            |                    | 4.4.4           | 28               |
| 11 | 144  | 147     | 144    | 26.2   | 26.2       | all        | 144                | 144             | 29               |
|    |      | 148     | 145    | 26.3   | 26.3       |            |                    |                 |                  |

Partial Support Behind a Flag

Global: 76.92% + 2.22% = 79.14%

# WebGPU (reminders)

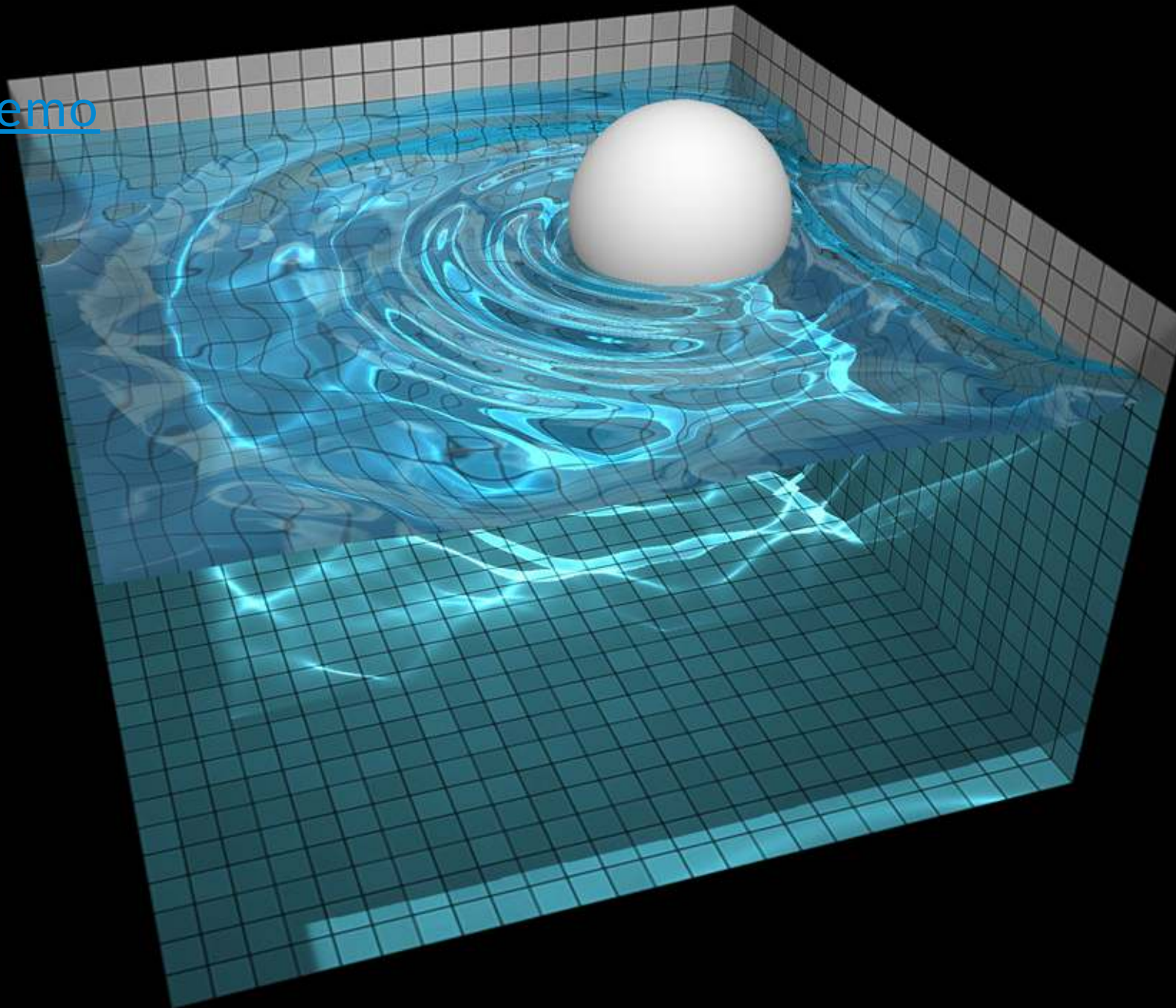
- low-level API, fast, promising, introduced by Apple
- close to [Metal](#), Vulkan and DirectX 12
  - [read Metal docs](#) to understand the concepts
- new shader language: [WGSL](#)
  - text format, gets compiled as SPIR-V (Vulkan) : [Slang](#) can help!
- **version 1.0 [released on Chrome \(and Edge\) in April 2023](#)**
- [Safari](#) and [Firefox](#) officially support since Summer 2025
- [official W3C spec](#), [demos](#), [minimalistic code sample](#)

➡ the future Web 3D API, **start playing with it!** 🎮

# Conclusion: which API should I use?

- **1** Start with **WebGL 1.0**, many examples (15-year-old API!)
  - to understand the *concepts*
    - state machine, pipeline, buffers, shaders
    - see OpenGL course!
  - and **how WebGL interacts with a web page**
    - see HTML / JavaScript / CSS course
- **2** Check new features introduced in **WebGL 2.0**
- **3** Use high-level APIs: [THREE.js](#), [Babylon](#), [A-Frame](#) etc.
  - for a smooth transition to [WebGPU](#)!

# WebGPU Demo



# WebGL

## Concepts

# Concepts > Syntax

- APIs evolve
- GPUs change too
- But all modern APIs and GPUs have **a lot in common**
- **Common, transposable concepts** are more important than **syntax** and APIs

➡ **understand how GPUs work** for **maximum performance**

➡ **transpose your knowledge easily** to other APIs, OSes or architectures

# CPU vs GPU

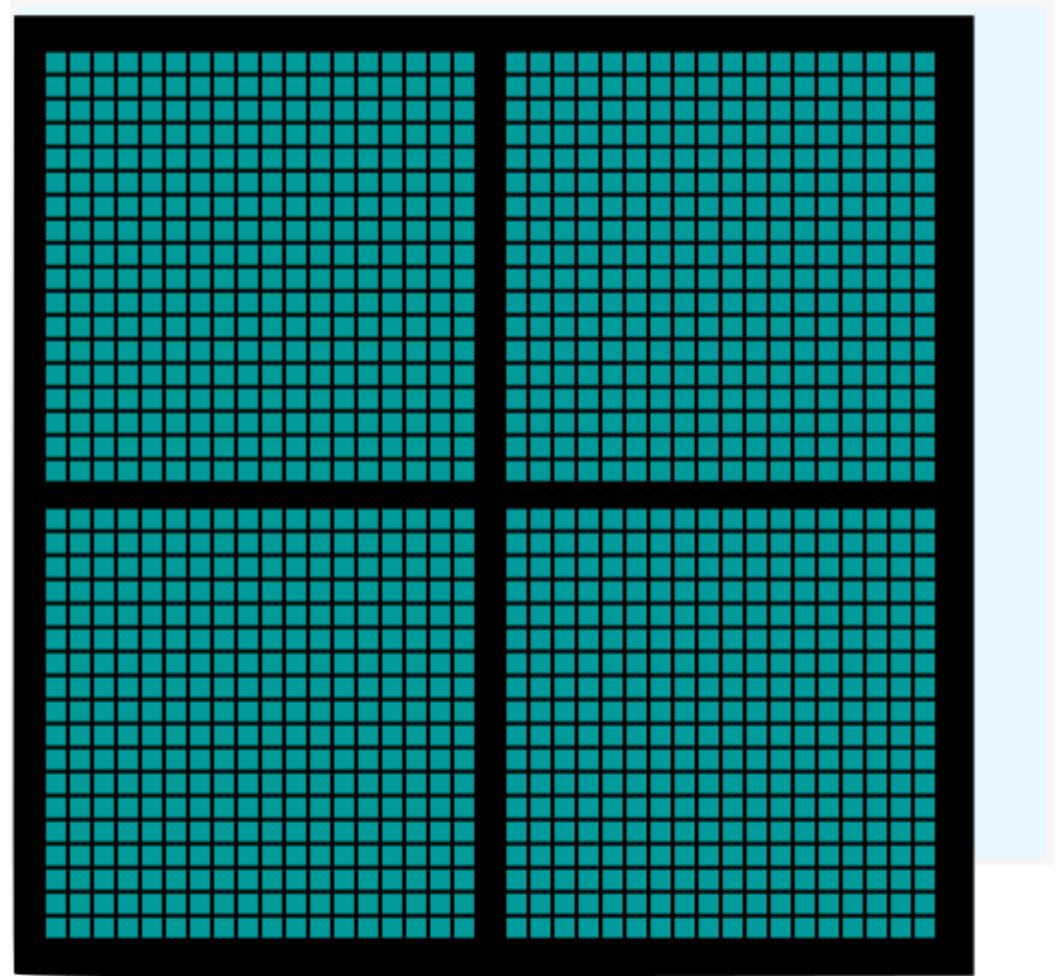
## Reminders

“ *There's a freaking supercomputer in your browser,  
and nobody seems to have noticed!* ”

[Steve Sanderson](#)

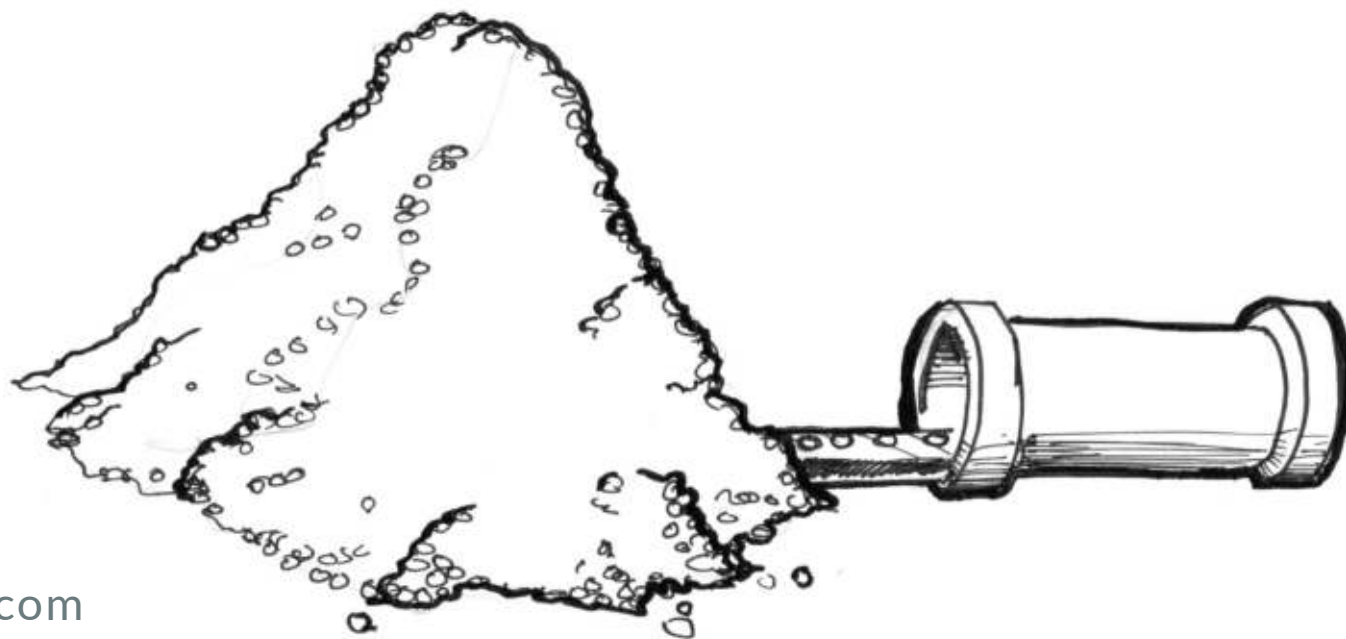
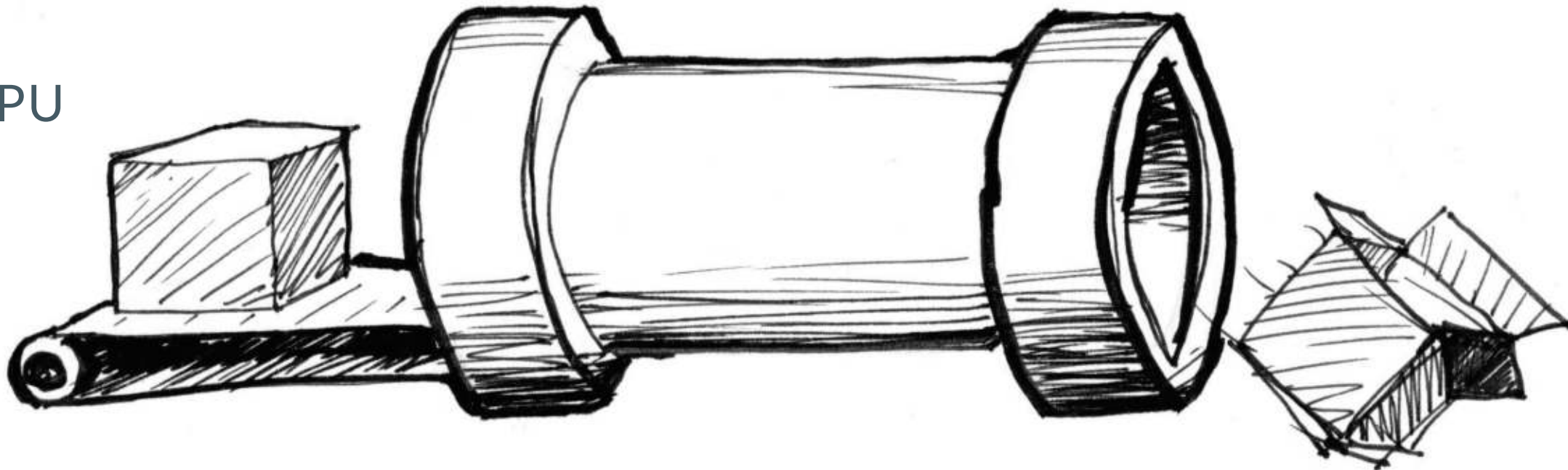


CPU  
Multiple Cores

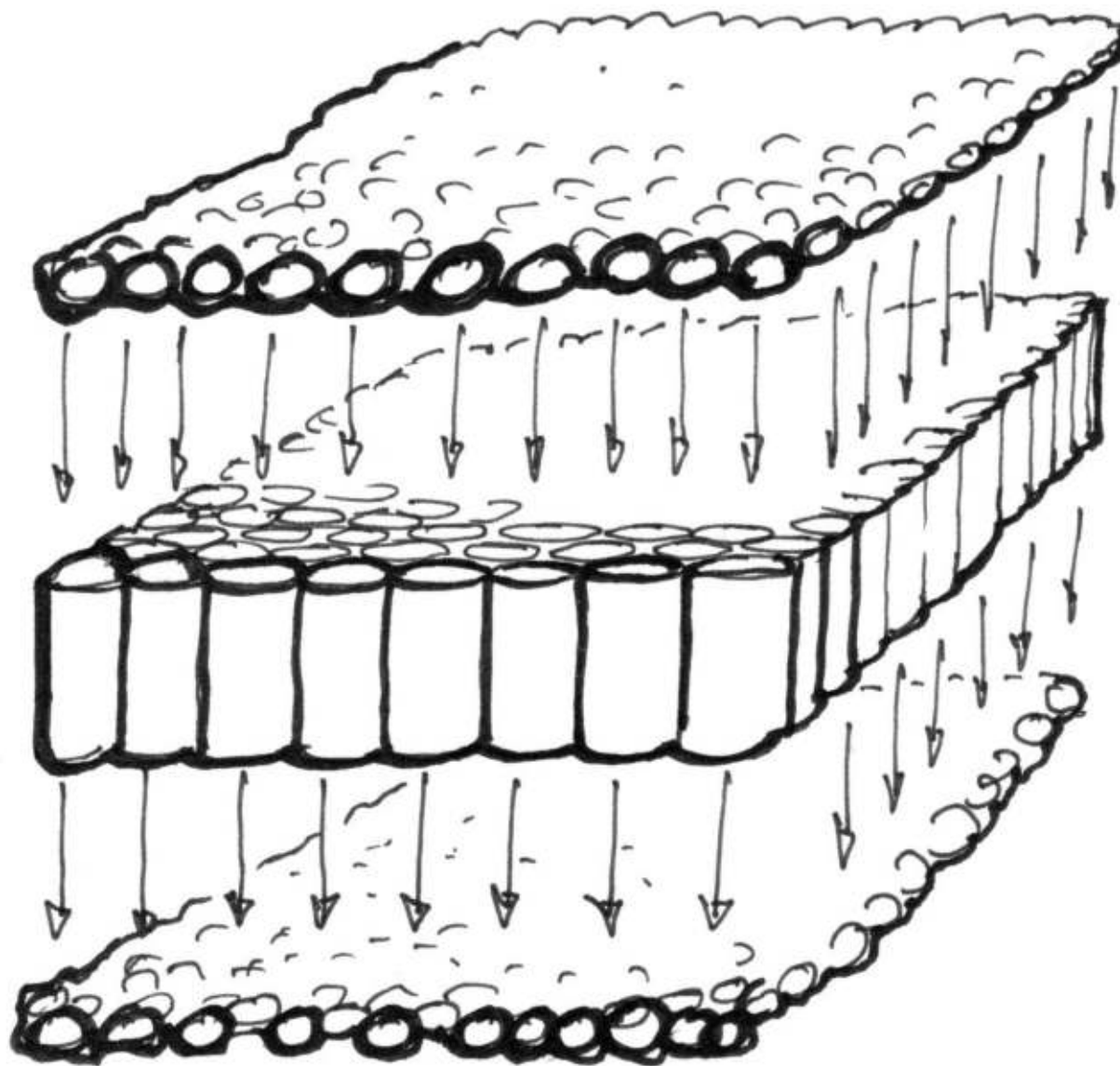


GPU  
Thousands of Cores

# CPU



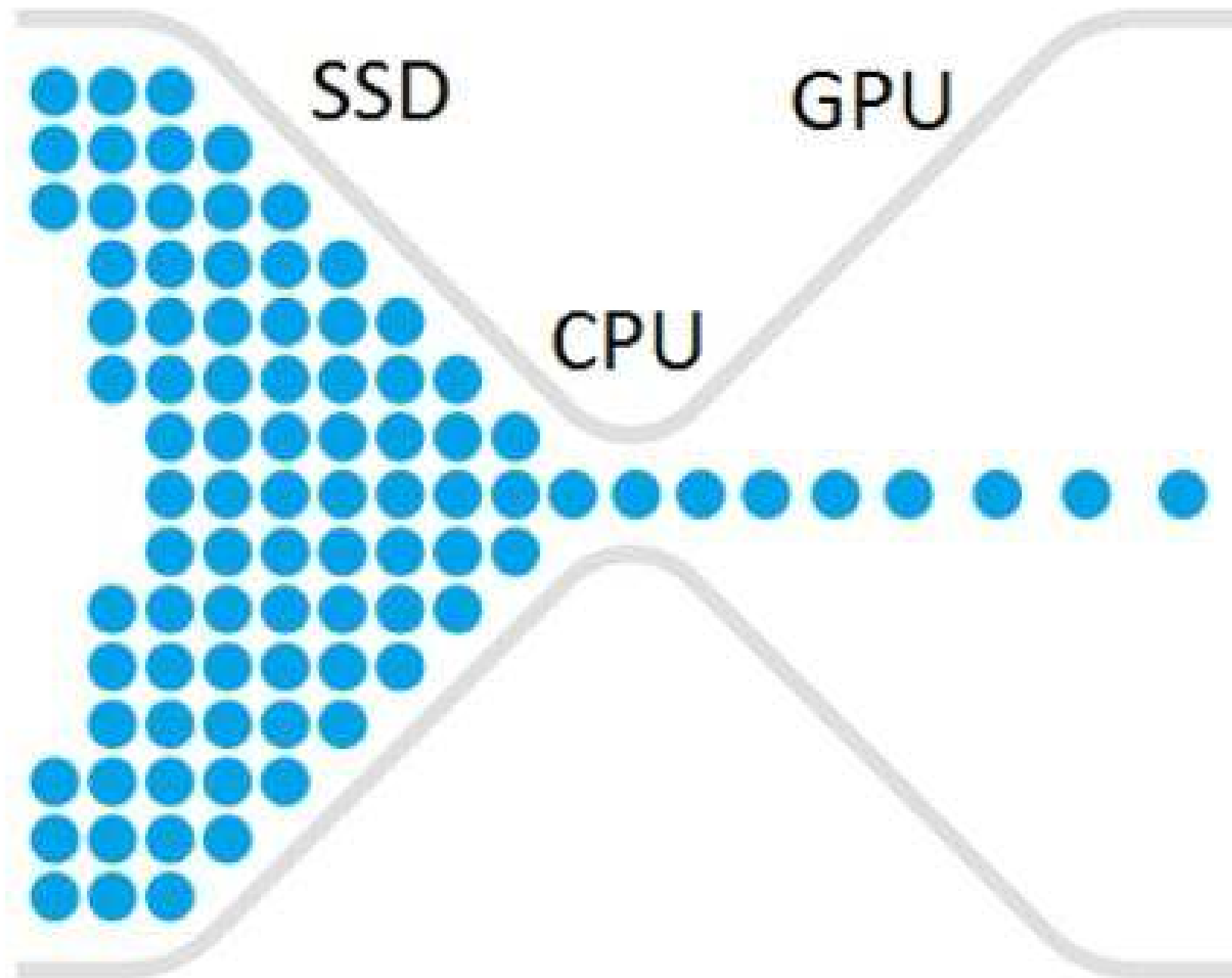
# GPU



# Goal

Send **as much data as possible to the GPU**, for **fast** processing

- **"upload"** (CPU ➡ GPU) is **slow** 🐢
  - group data into **buffers** before transfer
- **GPU processing is very fast**
  - using **shaders**
    - working in **parallel**
    - **simple** instructions
    - **compiled** in native low-level GPU code



# Constraints

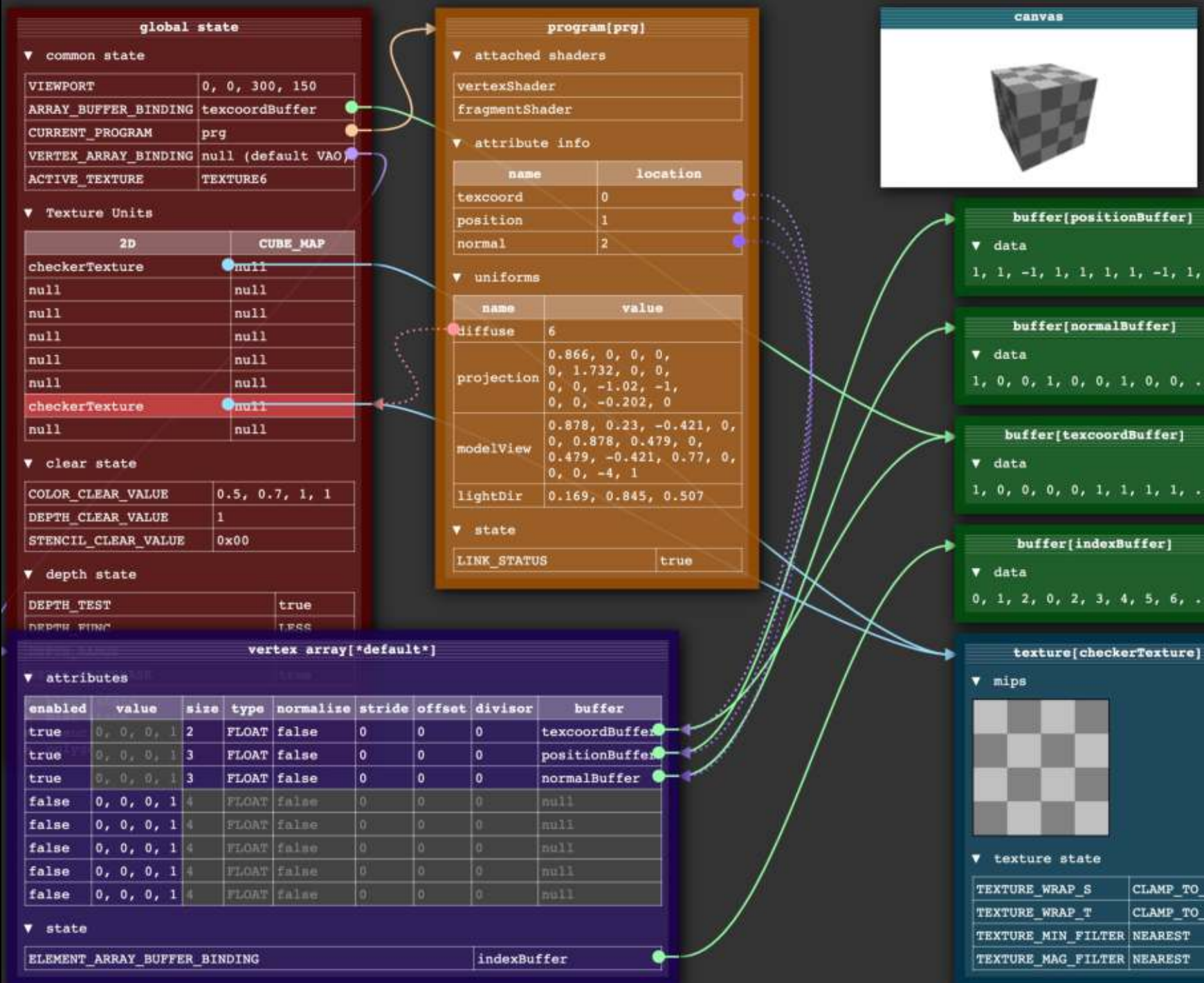
- Rendering is fast but "**download**" (CPU  GPU) **VERY** slow 🐌
- **Buffers are not flexible** for **dynamic** data
- **Arrays** must be converted to **textures** (for **GPGPU**)
  - **conversion** takes time especially for dynamic data
  - possible loss of **accuracy**
- **Shaders are complex** to write
  - pixels are **isolated**, processed in parallel, independently
  - instructions are **limited**
  - **optimizing** and **debugging** is not trivial!

# CPU



# OpenGL, is a **state machine**

Reminders

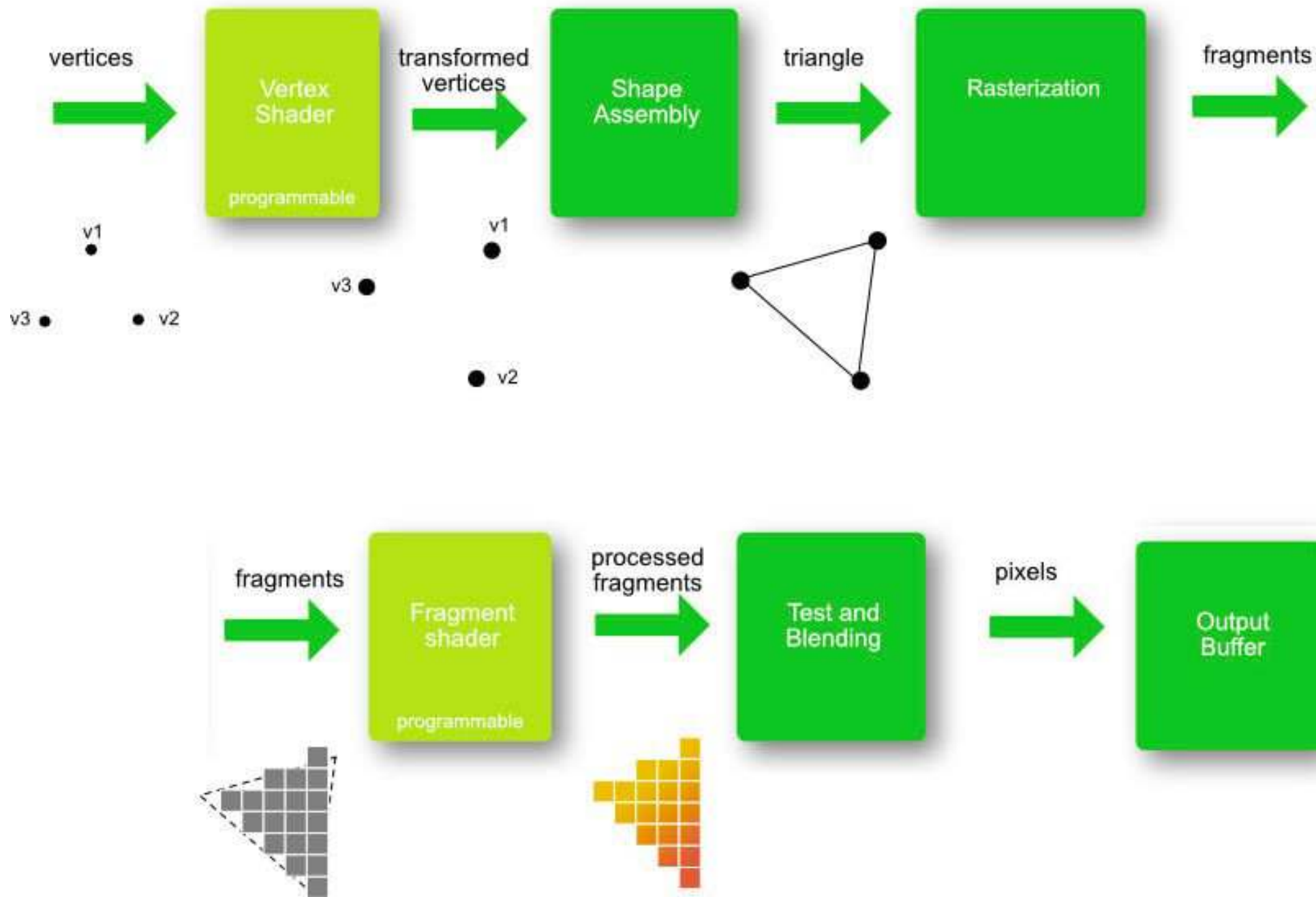


# WebGL is a state machine too!

- **data** preparation
  - format, type, buffers...
- **global state** preparation
  - color, blending...
- rendering
  - **send to GPU** for **shader** processing

# OpenGL Pipeline

Reminders



# Rasterization

*Interactive illustration*

[WebGL Fundamentals](#)

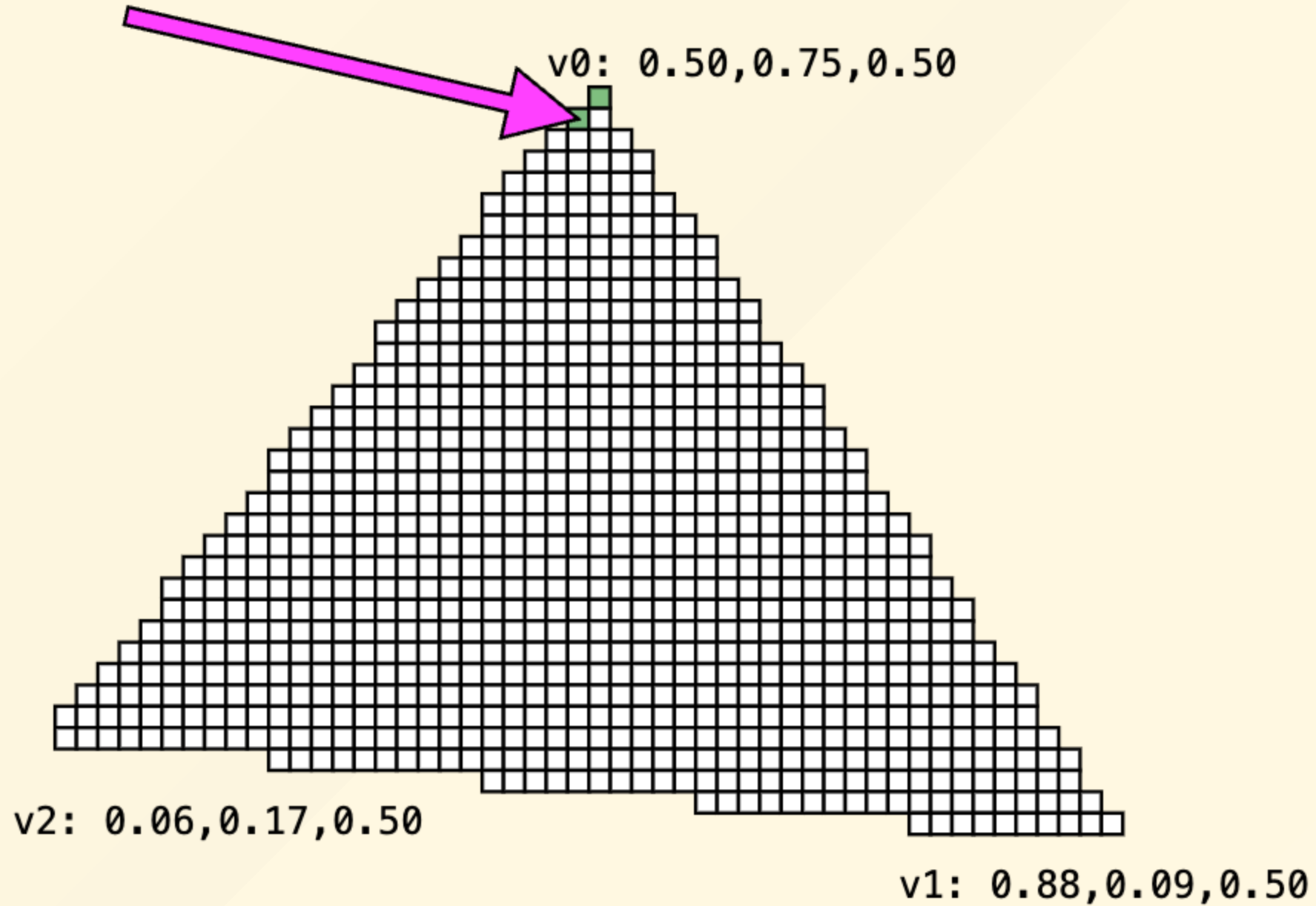
by

**Gregg Tavares** ([@greggman](#))

Chrome WebGL implementor

<https://webglfundamentals.org/webgl/lessons/resources/fragment-shader-anim.html>

```
v_color = 0.49,0.73,0.50  
gl_FragColor = v_color
```



# Shaders are essential

They allow to unleash the power of the GPU

- Shader code is **fast**
  - **thousands of specialized cores** inside a GPU!
  - once the data and the compiled code have been sent to the GPU, the performance is the same regardless of the language or API
- Rendering is **flexible**
  - the rendering pipeline was fixed, not programmable before 2001
  - "rendering" has been hijacked to perform fast parallel physics and machine learning computations on the GPU (**GPGPU**)

# Shader programming steps

- the application sends to the GPU:
  - **buffers** (vertices, normals, connectivity info...) and **textures**
  - **shaders** to compile and run
- **vertex shaders are called once per vertex** ★
- each primitive (point, line, triangle) is converted to fragments(*rasterization*)
- ~~pixel~~ **fragment shaders are called once per fragment** ★
  - their inputs (color, depth, normal) have been previously **interpolated using the points defining the primitive!**

# From the triangle to the pixel

*Interactive illustration*

**Making WebGL Dance**

by

**Steven Wittens**

<https://acko.net/files/fullfrontal/fullfrontal/webglmath/shaders.html>

Note: these slides use cutting edge CSS 3 and WebGL features. It is recommended to use Google Chrome to view them.

# *The Rise Of The Shaders*

# GLSL: Shader Programming Language

- **variable types** ★
  - **uniform: input**, sent by the app, **constant** in the shader code
  - **attribute: input** of the vertex shader, sent by the app: **data of the vertex buffer, varies per vertex**
  - **varying: output** of the vertex shader / **input** of the fragment shader
- **functions**: C language dialect
- GLSL for WebGL 1.0, cf [page 3](#)
- GLSL pour WebGL 2.0: version OpenGL ES 3.0, cf [page 8](#)

# WebGL

Let's code!

# BREAK

30' 

# Appendices

# Winter Forest by Schindelar3D

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# Gaussian What !?

## Rendering Gaussian Splats on the Web



Fivos  
DOGANIS

- WebGL History

<https://web.eecs.umich.edu/~sugih/courses/eecs487/lectures/20-History+ES+WebGL.pdf>

- WebGL 2 Course

<https://perso.univ-rennes1.fr/pierre.nerzic/IAI2/IMR2 - Synthèse d'images - CM2.pdf>

- Tools for analyzing, debugging, checking and dumping WebGL

<https://github.com/greggman/webgl-helpers#webgl-gl-error-checkjs>