KHRONOS® GROUP

Universal GPU Compressed Textures for glTF using KTX 2.0

April 2021

Tiffany-style Stained Glass Table Lamp
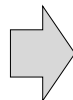*Model courtesy of Wayfair*

Enabling Compact and Efficient glTF Textures

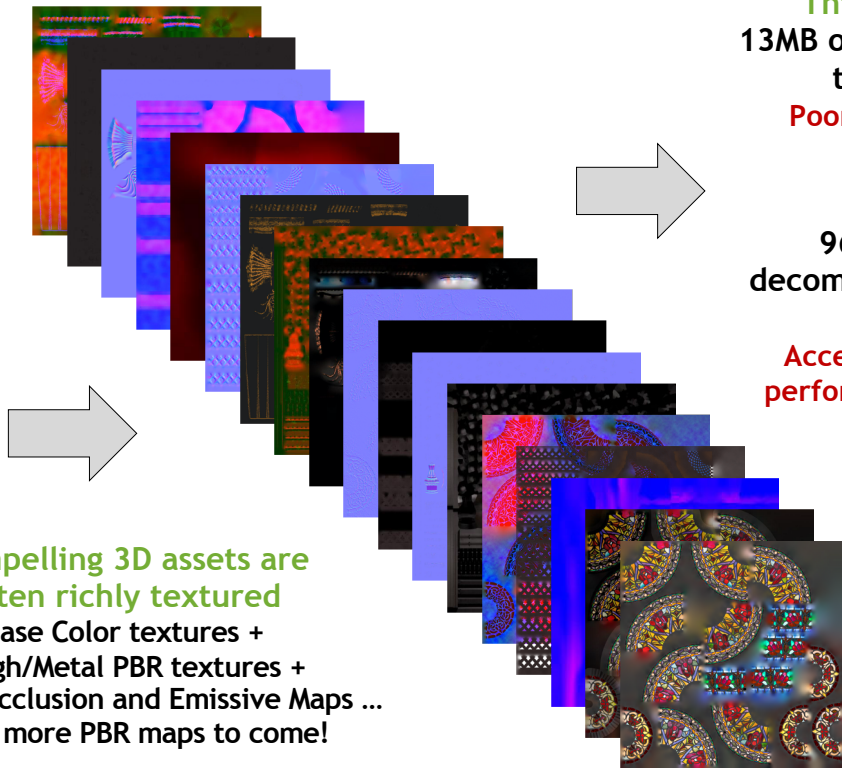**KTX™**

+

Basis Universal

Compression Technology

glTF can now use KTX 2.0 bitmap textures leveraging Basis Universal for compact, visually rich, assets that can be efficiently rendered on diverse platforms

Visually Rich Assets Use Many Large Textures

This lamp model contains
13MB of JPG and PNG compressed textures to download
Poor user responsiveness and data plan unfriendly

… and creates
96MB of textures when decompressed into GPU memory for rendering
Accessing large textures slows performance and eats battery on portable devices

Compelling 3D assets are often richly textured
Base Color textures +
Rough/Metal PBR textures +
Normal, Occlusion and Emissive Maps …
… and more PBR maps to come!

GPU Compressed Textures

GPU Memory Bandwidth is Precious

Accessing large uncompressed textures costs performance and power
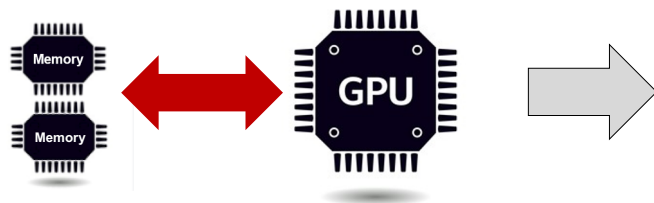
GPU Compressed Textures

GPUs can directly process compressed textures in memory if held in specialized block-based compressed formats designed for

Fast Decoding Speed and Random Access
Reduces GPU memory size and bandwidth = faster rendering

Encoding to GPU compressed formats is compute-intensive and so converting uncompressed images, JPGs or PNGs to GPU compressed textures at runtime is typically not feasible

So, why not just use GPU compressed textures in glTF 3D asset files...
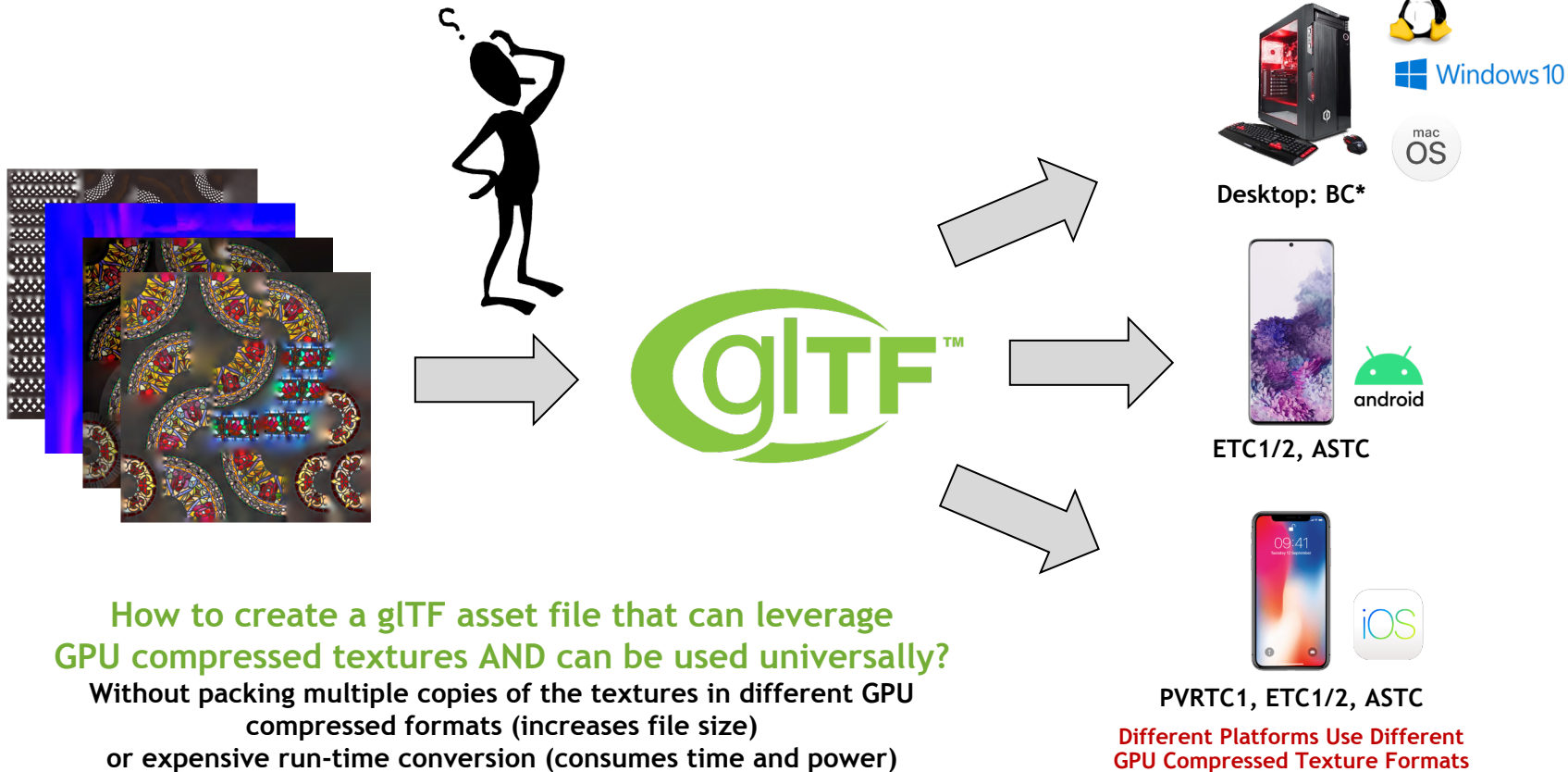...because of industry fragmentation!

GPU Compressed Texture Format Fragmentation
Multiple GPU Compressed Texture formats with varying levels of support across diverse platforms

	AMD	Apple Ax	Apple M1	ARM	Intel	NVIDIA Desktop	NVIDIA Tegra	Qualcomm
ASTC	✗	A8 and newer	✔	Mali-T620 and newer	Gen9 and newer	✗	✔	Adreno 3xx series and newer
BC1, BC3	✔	✗	✔	✗	✔	✔	✔	✗
BC7	Radeon HD 5000 series and newer	✗	✔	✗	Gen7 and newer	GeForce 400 and newer	✔	✗
ETC1	✗	A7 and newer	✔	Mali-300 and newer	Gen8 and newer	✗	✔	Adreno 2xx series and newer
ETC2	✗	A7 and newer	✔	Mali-T6xx and newer	Gen8 and newer	✗	✔	Adreno 3xx series and newer
PVRTC1	✗	✔	✔	✗	✗	✗	✗	✗

The Need for Universal GPU Textures

Desktop: BC*

ETC1/2, ASTC

PVRTC1, ETC1/2, ASTC

**Different Platforms Use Different
GPU Compressed Texture Formats**

**How to create a glTF asset file that can leverage
GPU compressed textures AND can be used universally?**
Without packing multiple copies of the textures in different GPU
compressed formats (increases file size)
or expensive run-time conversion (consumes time and power)

Basis Universal Texture Compression

BINOMIAL

Basis Universal technology, developed by Binomial, with open source transcoders released in partnership with Google, enables compact supercompressed textures that can be efficiently transcoded to diverse GPU Compressed Texture formats at run-time

Basis Universal has two modes: 'UASTC' and 'ETC1S'

Use Case	Baseline Khronos Compressed Texture Format	Format with selected modes	LZ-Based Supercompression	Supercompressed bits per pixel (*typical* rates for 24-bit textures)	Compressed Image Comparison (*typical* rates for 24-bit textures)
Highest Quality	ASTC (8bpp includes alpha)	UASTC	Optional RDO Encoding + zstd	6bpp	PNG 6bpp
Smallest Size	ETC1 (4bpp, 8bpp with alpha)	ETC1S	Custom BasisLZ	1.0bpp	JPG 1.5bpp

Color textures can often use ETC1S mode with little to no loss of visual quality
Normal maps often need higher precision and typically use UASTC mode
Final asset size will depend on modes used

Khronos has developed KTX 2.0 Artist and Developer Guides to provide insights when
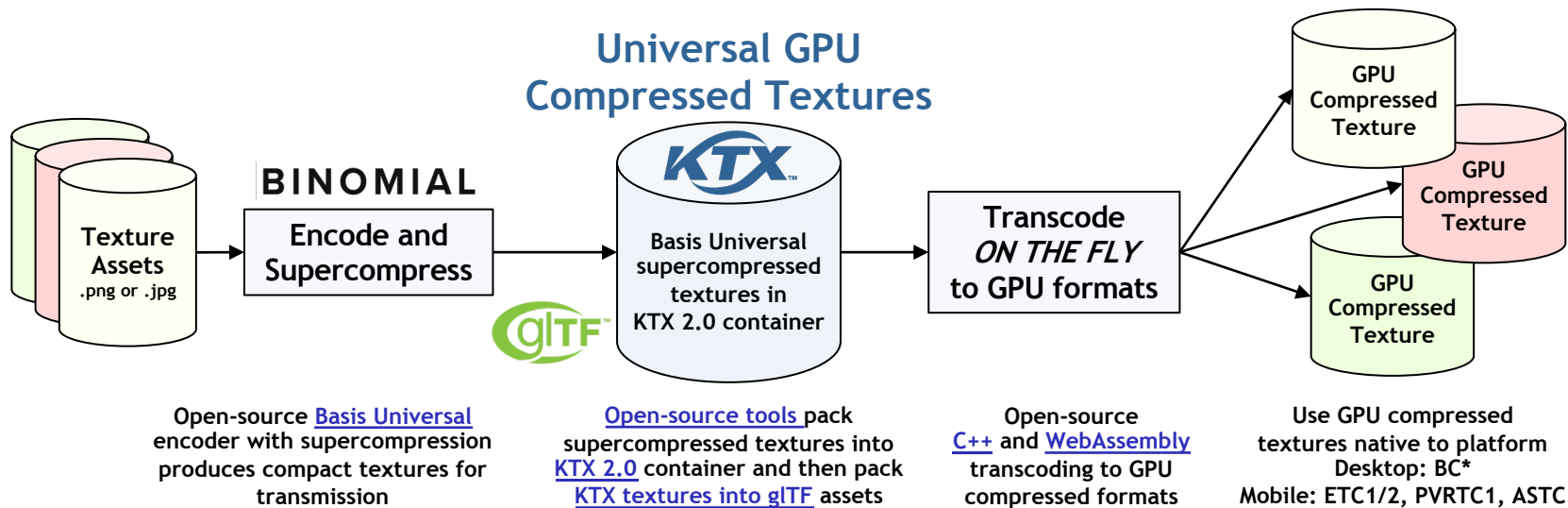different modes should be used and how to efficiently create and use universal GPU compressed textures

Khronos KTX 2.0 and Basis Universal
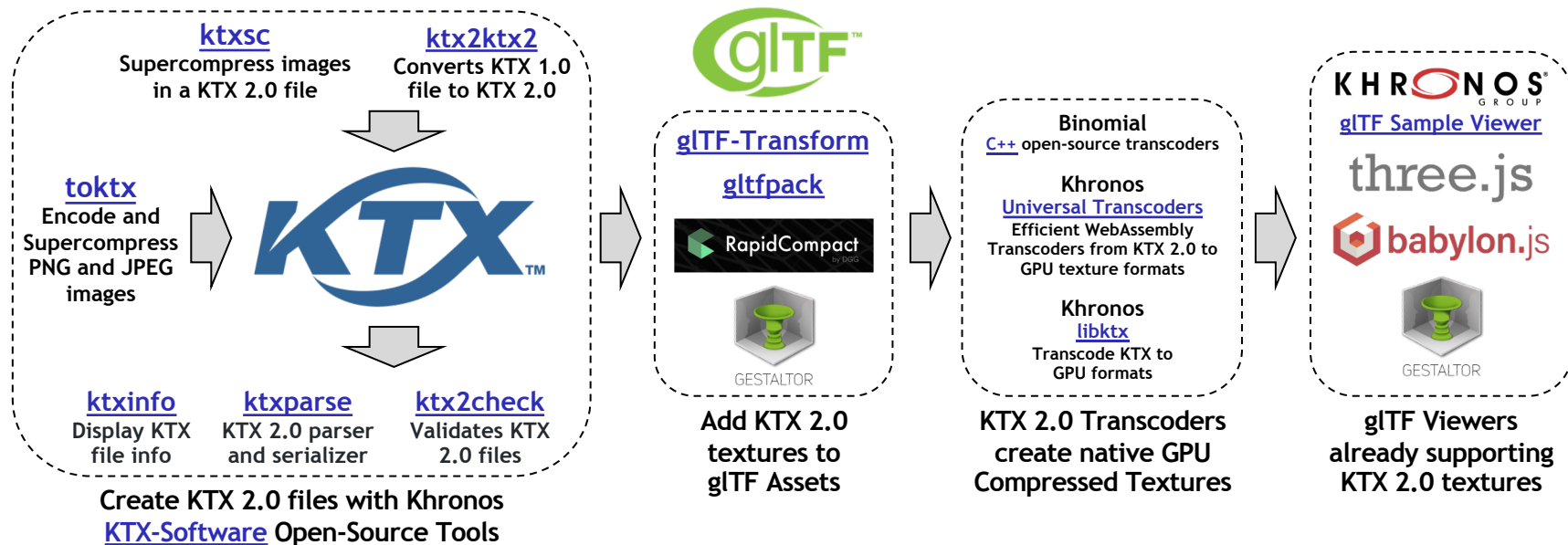
KTX (Khronos Texture)
Lightweight container format for consistent, cross-vendor distribution of textures
Contains all parameters needed for texture loading, including mipmap level access e.g., for LOD streaming
Supports wide range of texture formats used in Vulkan, OpenGL and other GPU APIs

KTX 2.0 adds support for Basis Universal supercompressed textures
KTX 2.0 can hold Basis Universal textures in UASTC or ETC1S modes
glTF KHR_texture_basisu extension enables glTF to use KTX 2.0 textures

Universal GPU Compressed Textures

Texture Assets .png or .jpg → **BINOMIAL Encode and Supercompress** → **KTX** **Basis Universal supercompressed textures in KTX 2.0 container** (glTF) → **Transcode ON THE FLY to GPU formats** → **GPU Compressed Texture**, **GPU Compressed Texture**, **GPU Compressed Texture**

Open-source Basis Universal encoder with supercompression produces compact textures for transmission

Open-source tools pack supercompressed textures into KTX 2.0 container and then pack KTX textures into glTF assets

Open-source C++ and WebAssembly transcoding to GPU compressed formats

Use GPU compressed textures native to platform
Desktop: BC*
Mobile: ETC1/2, PVRTC1, ASTC

Khronos KTX 2.0 Tools and Viewer Details

ktxsc
Supercompress images in a KTX 2.0 file

ktx2ktx2
Converts KTX 1.0 file to KTX 2.0

toktx
Encode and Supercompress PNG and JPEG images

KTX™

ktxinfo
Display KTX file info

ktxparse
KTX 2.0 parser and serializer

ktx2check
Validates KTX 2.0 files

Create KTX 2.0 files with Khronos
KTX-Software Open-Source Tools

glTF™

glTF-Transform

gltfpack

RapidCompact
by DGG

GESTALTOR

Add KTX 2.0 textures to glTF Assets

Binomial
C++ open-source transcoders

Khronos
Universal Transcoders
Efficient WebAssembly Transcoders from KTX 2.0 to GPU texture formats

Khronos
libktx
Transcode KTX to GPU formats

KTX 2.0 Transcoders create native GPU Compressed Textures

KHRONOS GROUP

glTF Sample Viewer

three.js

babylon.js

GESTALTOR

glTF Viewers already supporting KTX 2.0 textures

The Results

(300% zoom)
JPG + PNG
File size: 12.8 MB
Memory: 96.2 MB

(300% zoom)
KTX: UASTC + ETC1S
File size: 10.4 MB
Memory: 21.4 MB

(300% zoom)
KTX: ETC1S
File size: 4.6 MB
Memory: 15.7 MB

Models downloadable here

Call to Action

KTX 2.0 textures with Basis Universal supercompression and the glTF KHR_texture_basisu extension are here!

Enables glTF assets with compact, high-quality textures that can be efficiently converted to GPU compressed textures on diverse target platforms to reduce asset file download sizes AND GPU memory usage

Tools Vendors
Use open-source tools to create, convert, inspect, validate and transcode KTX 2.0 supercompressed textures to add KTX 2.0 supercompressed assets to your glTF exporter!

Application and Engine developers
Use optimized transcoders to integrate KTX 2.0 import and display!

Artists and Developers
Give us feedback on the KTX 2.0 Developer Guide and Artist Guide!

KTX 2.0 Resources

- **Khronos KTX Specification**

- **glTF KHR_texture_basisu Extension Specification**

- **Binomial Basis Universal Documentation**

- **Khronos KTX 2.0 Artist and Developer Guides**

- **KTX Software Tools**

- **Khronos WebAssembly KTX 2.0 transcoders**

- **Tiffany Lamp Asset**

- **Babylon side by sides**
  - KTX Basis-U UASTC/ETC1S vs. JPEG/PNG https://playground.babylonjs.com/full.html#YD2TXP#23
  - KTX Basis-U ETC1S vs. JPEG/PNG https://playground.babylonjs.com/full.html#YD2TXP#22

- **Babylon.js KTX Documentation**

- **glTF-Transform**

- **Gestaltor**

- **RapidCompact**

Khronos and glTF
Background Materials

April 2021

3D Authoring Tools

3DS MAX · Paint 3D · blender · Modo · MARMOSET TOOLBAG · SOLIDWORKS · Houdini · Cheetah3d model + animate + render · UU3D v3 (64-bit) · MAYA · Titania · CINEMA 4D · RealityServer · SUBSTANCE PAINTER · AUTODESK REVIT · VoxEdit · Dust3D · KeyShot by Luxion · SketchUp · Creature · MINECRAFT · Archilogic · Adobe Dn

VR / AR Authoring Tools

Microsoft Maquette · 8TH WALL · spoke by mozilla make your space · Oculus UNBOUND · medium · wave engine · VECTARY

3D Scanning Tools

HUAWEI 3D Live Object · QLONE · eCapture 3D · Sony 3D Creator · 3D · scandy

Convertors, Optimizers and Loaders

VNTANA · SIMPLYGON · RapidCompact by DGG · gltfpack · cgltf · Assimp Open Asset Import Library · PiXYZ SOFTWARE · SAFE SOFTWARE · Collada2gltf · CrossManager · OBJ2GLTF · FBX2glTF

Validation and Reference Tools

gltf-vscode · AGI · glTF Sample Viewer · Microsoft · glTF-Toolkit · glTF-validator · glTF-asset-generator

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Discover — Repositories

Smithsonian · cgtrader · EF EVE · TURBOSQUID · KENNEY ケニー · Sketchfab · Poly poly.google.com

Create — Tools

Experience — Apps / Engines

glTF™

3D Asset Format for Efficient Transmission and Processing

https://github.khronos.org/glTF-Project-Explorer/

Drive Demand — Users

Continental · web3D CONSORTIUM · OGC · otoy · AMD · NVIDIA · EA · IKEA · Bentley · wayfair · Uber · shopify · TARGET · VRM CONSORTIUM

Game Engines

UNREAL ENGINE · PLAYCANVAS · THE FORGE · unity · JMonkeyEngine · GODOT Game engine · OGRE · Diligent Graphics

Web Engines

babylon.js · CLAYGL · Ashes · model-viewer · xeogl · GLStudio · GLBoost · three.js

Apps and Engines

3D Builder 3D printing · CESIUM · COMSOL · AUTODESK FORGE · seek · Microsoft Flight Simulator · VENTUZ · Filament · CANDERA CGISTUDIO · KDAB · VTK · instant3Dhub · STK · esri · emersya · xeogl · GESTALTOR · Qt · ParaView · HYPAR

VR / AR Apps and Engines

WebXR · magic leap · hubs by mozilla · Mixed Reality Viewer · Amazon Sumerian · MESHROOM3D · JANUSVR · AUCTA · Worldviz where virtual becomes reality · arvizio · A-FRAME · goopy STUDIO · ARCore · Windows Mixed Reality Home · React 360 · THE WILD

Productivity and Social Apps

Office · facebook · WordPress

Core glTF 2.0 Asset Structure

.gltf (JSON)
Node hierarchy, PBR material textures, cameras

.bin
Geometry: vertices and indices
Animation: key-frames
Skins: inverse-bind matrices

.png
.jpg
.ktx
Textures

The picture can't be displayed.
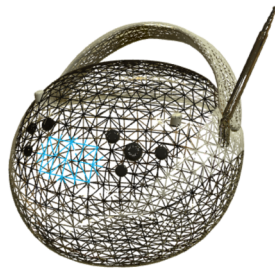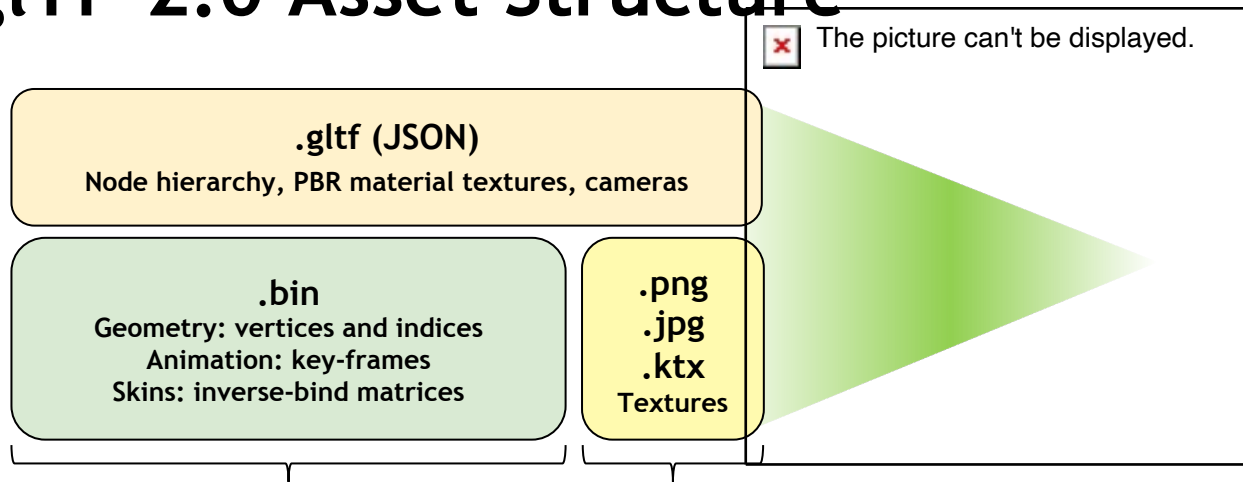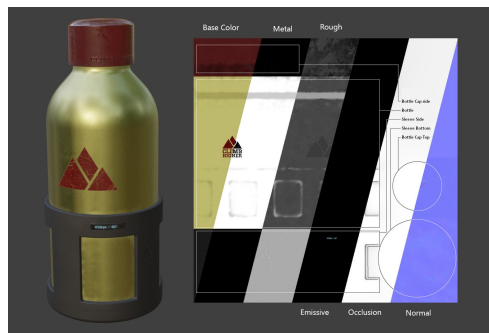
Geometry

Texture based
PBR materials

glTF Draco Mesh Compression Extension

- **glTF extension for compressed geometry**
  - Typically 10-25x geometry size reduction

- **Google Draco technology - designed for decompression efficiency and speed**
  - https://github.com/google/draco

- **Draco geometry encoders and decoders in open source**
  - C++ source code encoder
  - C++ and JavaScript decoders
  - https://github.com/google/draco/tree/gltf_2.0_draco_extension

- **glTF Draco compression adoption is growing in tools, applications and engines**
  - glTF pipeline, FBX2glTF, AMD Compressonator and glTF sample models

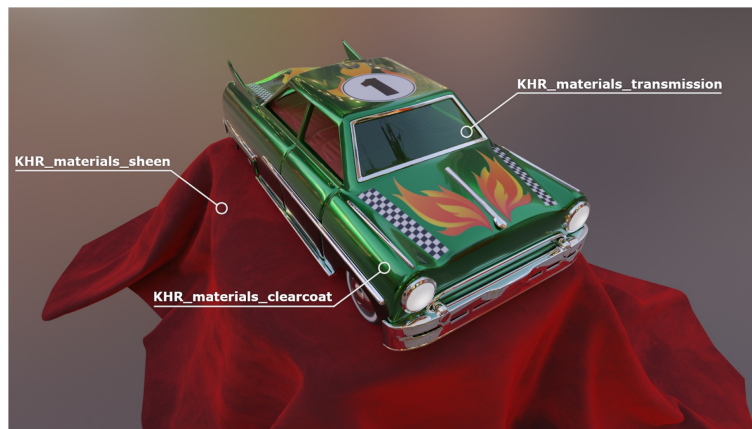
Mesh Compression Ratios
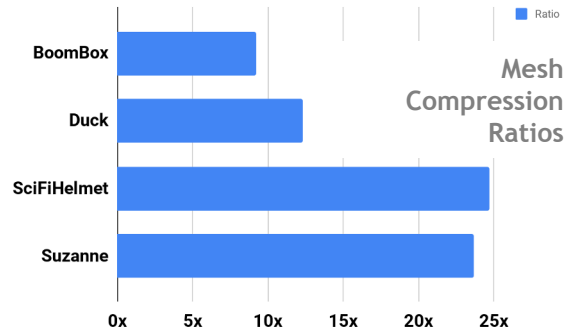
glTF PBR Materials Roadmap

Creating a rich physically-based material framework for the glTF ecosystem
glTF extensions add PBR material parameters that integrate with existing materials
Building consensus on interoperable PBR deployable on diverse platforms and devices

Roadmap includes requirements from Khronos 3D Commerce Working Group

KHR_materials_transmission

KHR_materials_sheen

KHR_materials_clearcoat

Water Bottle sample is CC0, by Microsoft

https://belcour.github.io/blog/research/2017/05/01/brdf-thin-film.html

June 2017
Core glTF 2.0
Mandatory Metallic-Roughness
Optional Specular-Glossiness

December 2020
First Wave glTF PBR Extensions
Clear Coat
Transmission
Sheen

Future Waves of
glTF PBR Extensions
Subsurface Scattering, Attenuation,
Index of Refraction (IOR), Thickness, Specular Color,
Anisotropy, Translucency, Thin Film (iridescence)
and more...