



RACECAR

Modern real-time car rendering in Vulkan

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Meet the (Race) Engineers



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Introducing RACECAR

- High fidelity real-time car rendering engine in C++/Vulkan
 - ◆ Inspired by games like *Gran Turismo 7*, *Forza*, Formula 1
- RACECAR aims for:
 - ◆ High quality reflections
 - ◆ Realistic, physically-based car material rendering
 - ◆ Photorealistic atmospheric lighting for outdoor scenes





Breaking down the problem

To achieve our goal of rendering high quality cars in real-time, we broke it down into four subproblems...



Atmospherics: physically-based sky rendering, precomputed LUTs, volumetric clouds



Ray tracing: combination of shadows, reflections, and image-based lighting (IBL)

Breaking down the problem

To achieve our goal of rendering high quality cars in real-time, we broke it down into four subproblems...



Car materials: PBR-based, glints, microflakes, clearcoat



Post-processing: bloom, SSAO, TAA, tonemapping

Terrain

What good is a car if it doesn't have anything to drive on

- Procedural heightmap
- Hardware tessellation for LODs
- Terrain "wetness" factor and "snow" factor

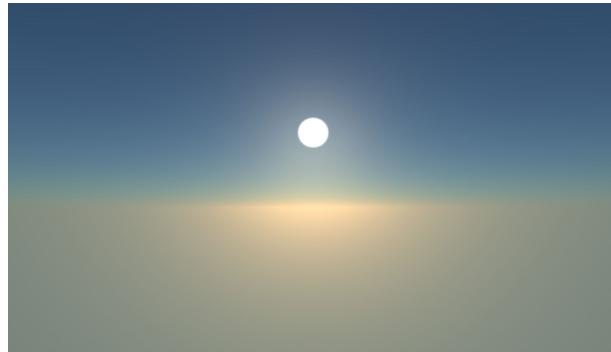


Atmospherics

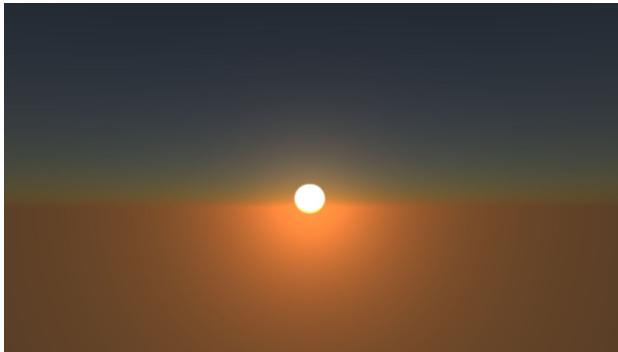
Physically-based atmospheric scattering



Sun is high in the sky



Approaching sunset



Sunset

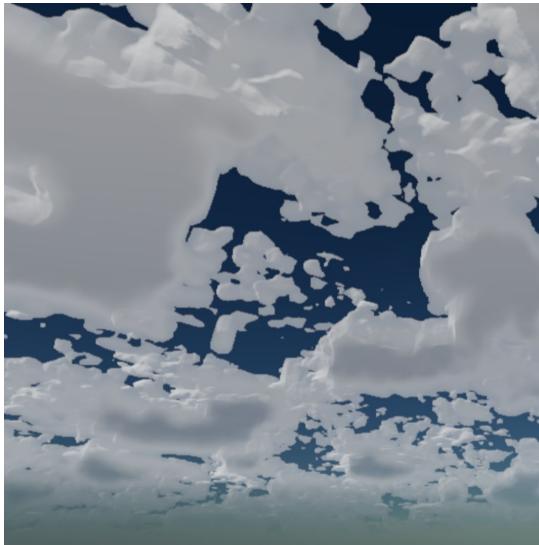


Outside Earth's atmosphere

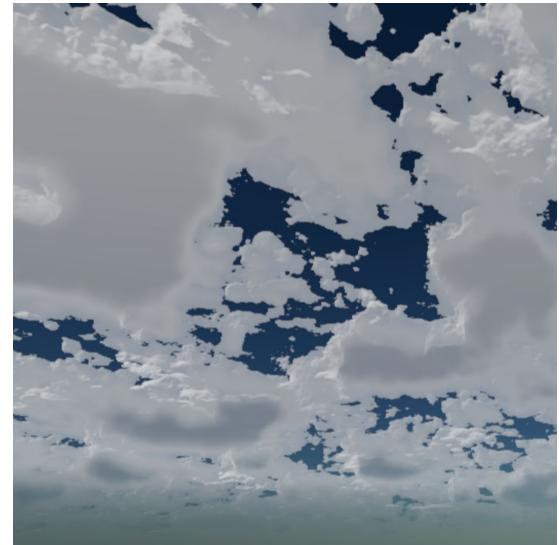
Volumetric clouds



Cumulus map

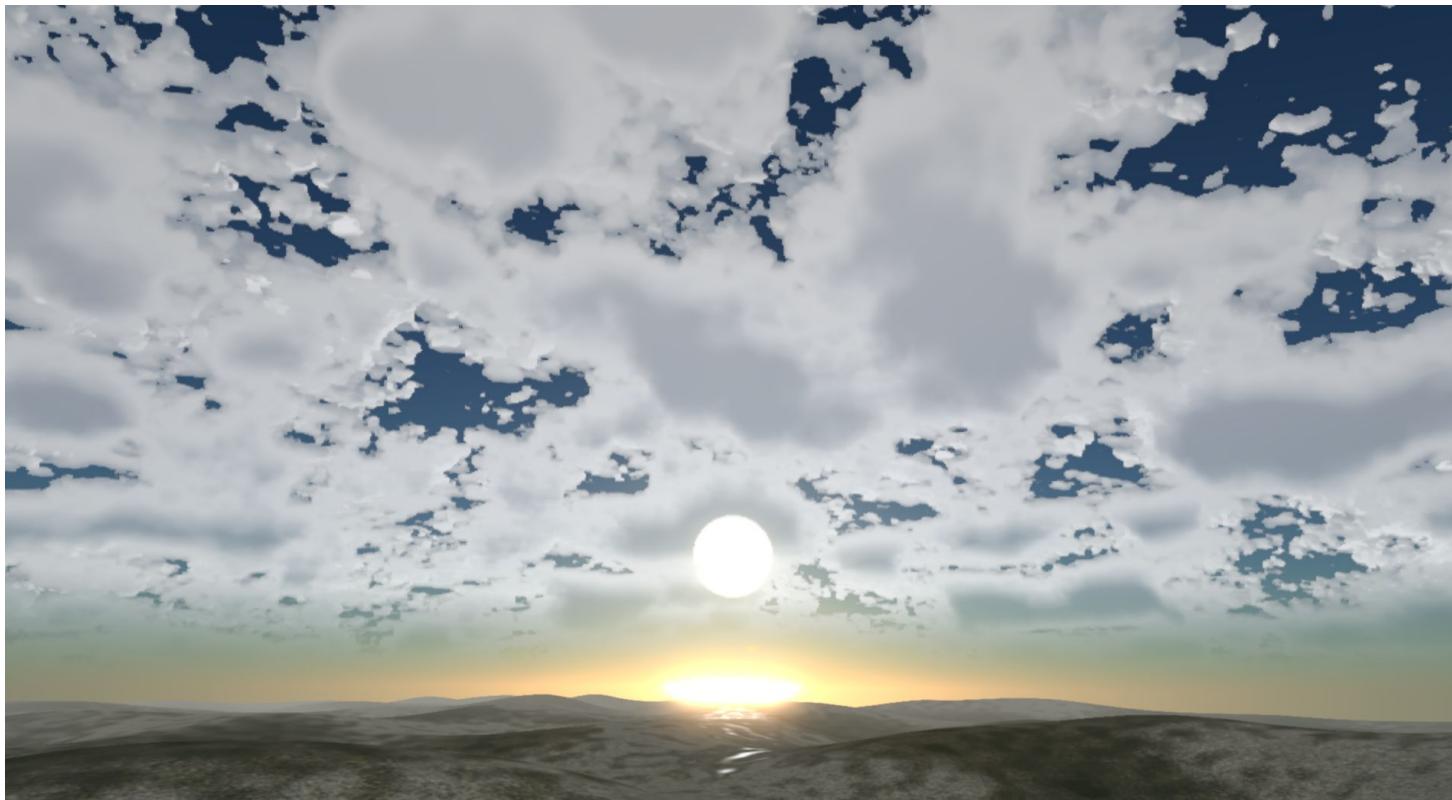


With low frequency noise



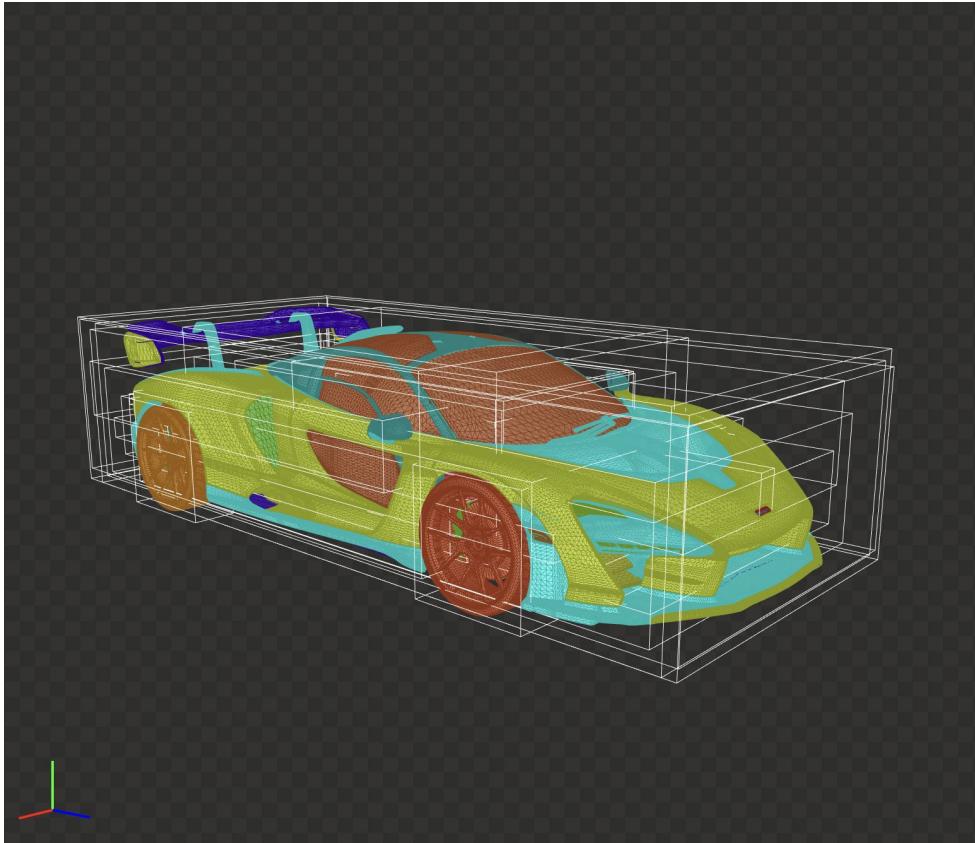
With low + high frequency noise

Final Result



Hardware ray tracing

Acceleration Structures



- Features a full ray tracing pipeline and material system
- Making use of Vulkan hardware acceleration structures



No shadows

A blue sports car, possibly a McLaren, is shown from a rear three-quarter perspective driving away on a dark, textured road. The background features rolling hills and a cloudy sky.

SSAO

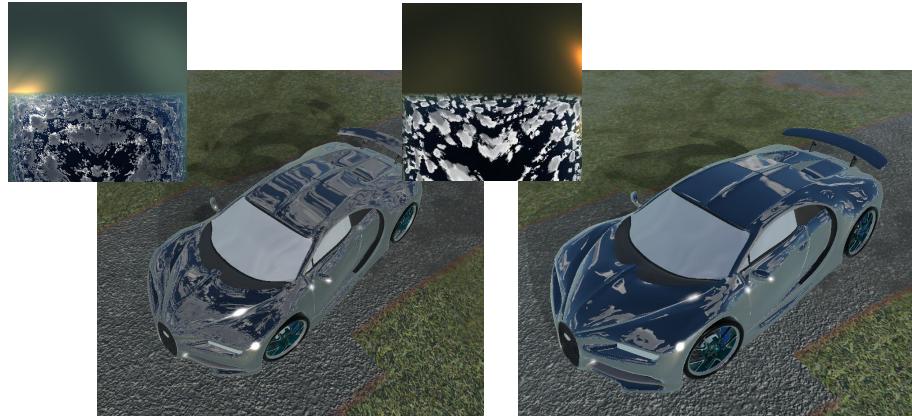


SSAO + Ray Traced Shadows

Reflections and image based lighting



Porsche using IBL reflections



High-frequency
detail, visually messy

Low-frequency,
cheaper and nicer

Ray traced reflections



Total Specular Reflection
(Puddles)

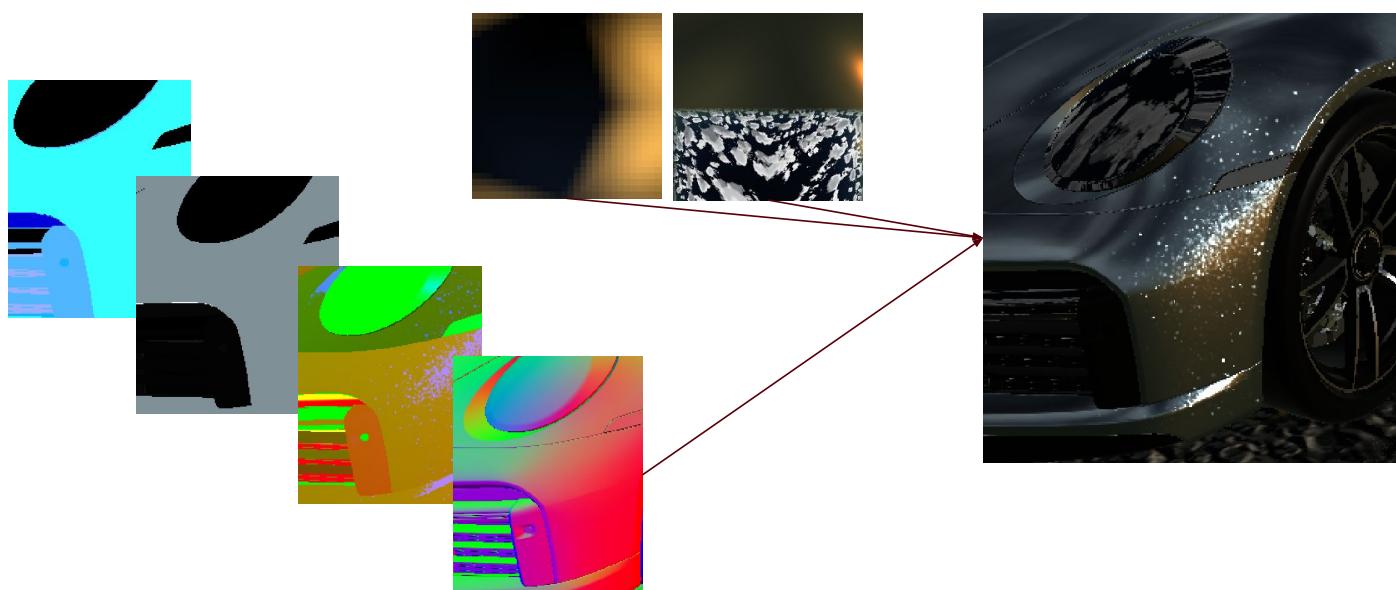


Rough Normal Reflection
(Wet ground)

Car material rendering

Car materials

- Car materials are complex - often made of many different layers stacked together
- Approximate realistic car-material rendering via PBR
- Support multi-layer finishes for microflakes and clearcoat



Microflakes

- Microflakes are rendered using Deliot's 2023 paper on anisotropic glint rendering
 - ◆ Controllable log-density and other params help simulate microflakes



Real life reference

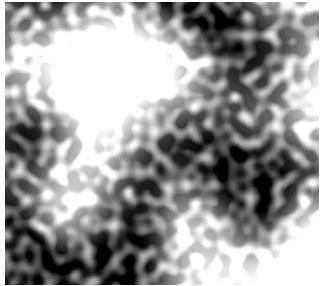


Our rendered glints

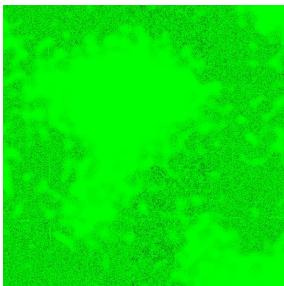
Renders



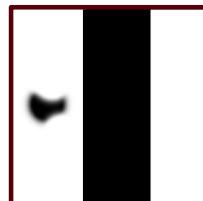
Procedural terrain and lighting



Overall glossiness



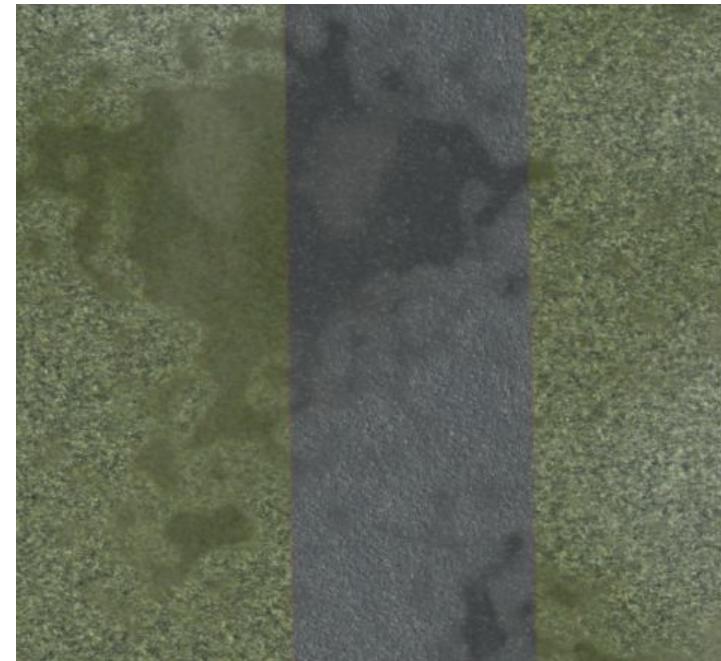
Overall normal



Layer mask



Overall albedo

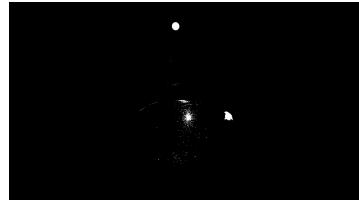


Final terrain

For puddles, we use Uncharted 4's wet surface shaders.

Compute-based post-processing

Bloom



Brightness threshold



Downsampling

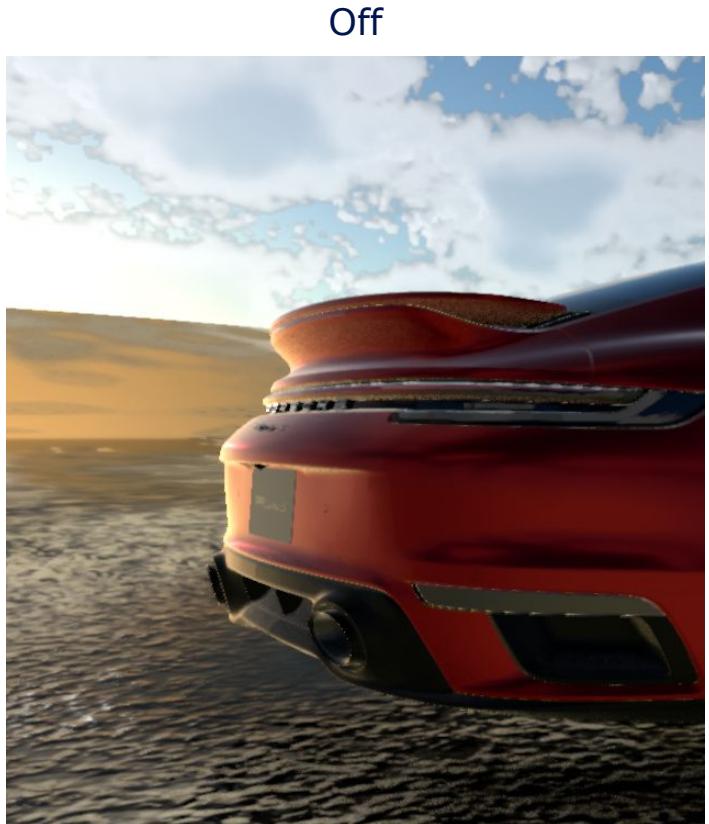


Upsampling

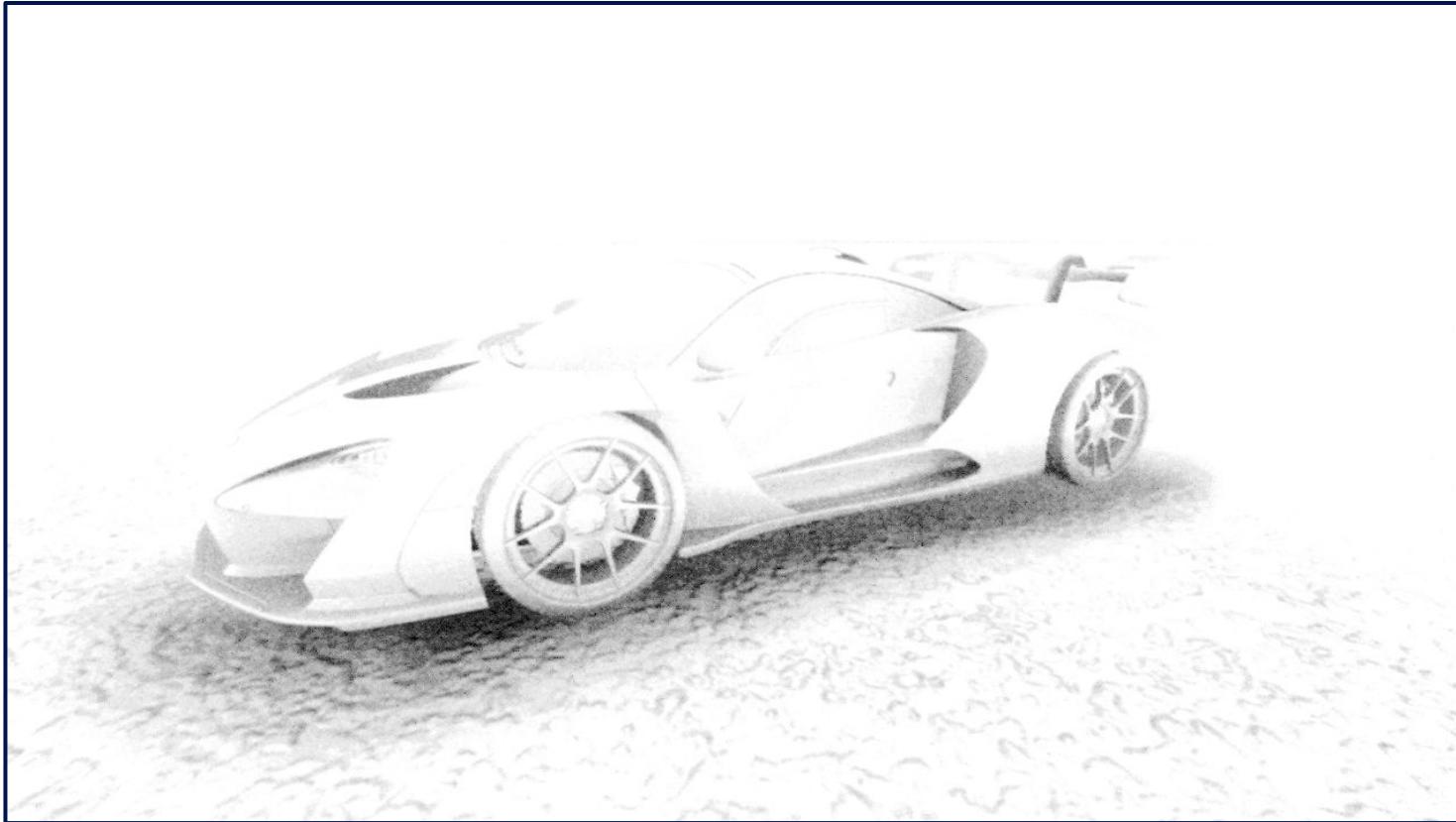


Final gather

Bloom

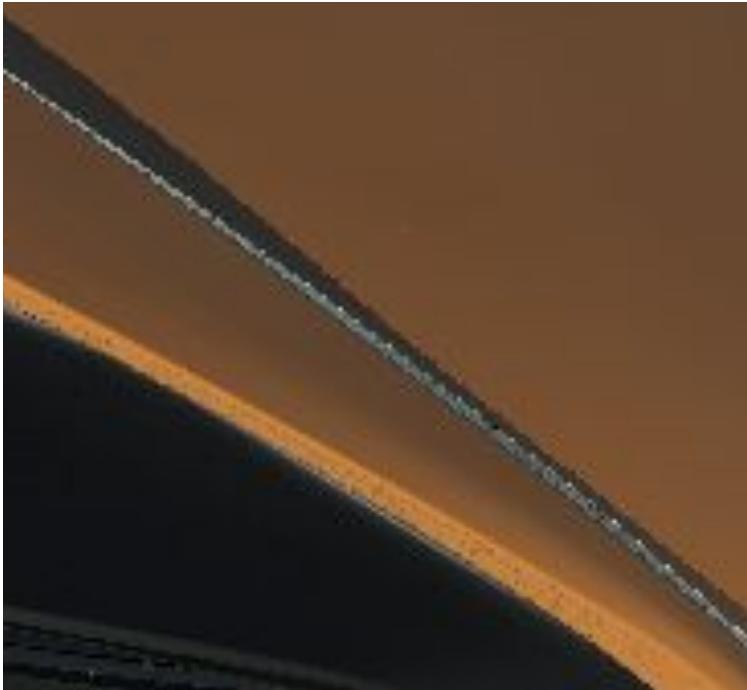


Screen space ambient occlusion (SSAO)

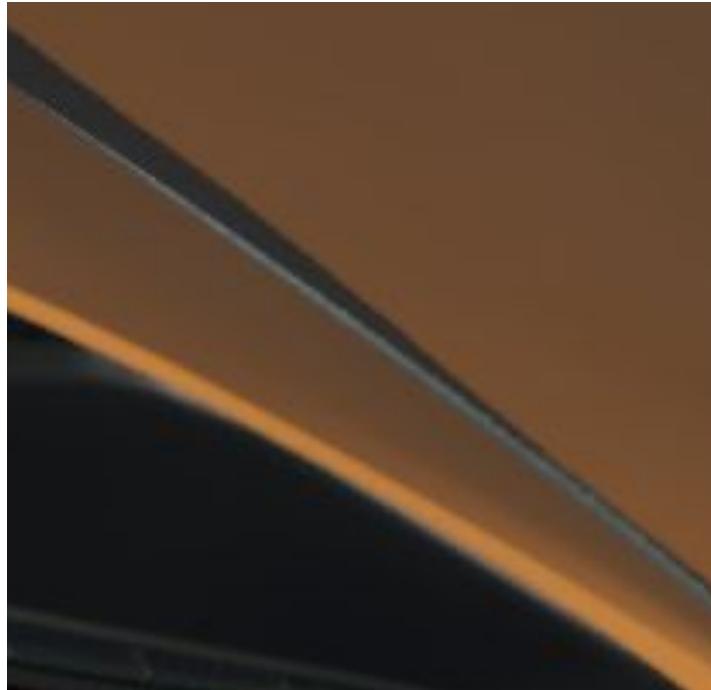


Temporal anti-aliasing (TAA)

Before



After



Tonemapping

None



Reinhard



ACES 1



Final choice: GT 7 tonemapping
(we promise this looks different)

The background of the slide features a desert landscape under a cloudy sky at sunset. A Formula 1 race car is positioned in the lower right foreground, angled towards the left. The car has a white body with red and gold accents. The sky is filled with large, billowing clouds, and the sun is visible on the horizon, casting a warm glow over the scene.

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