chaos

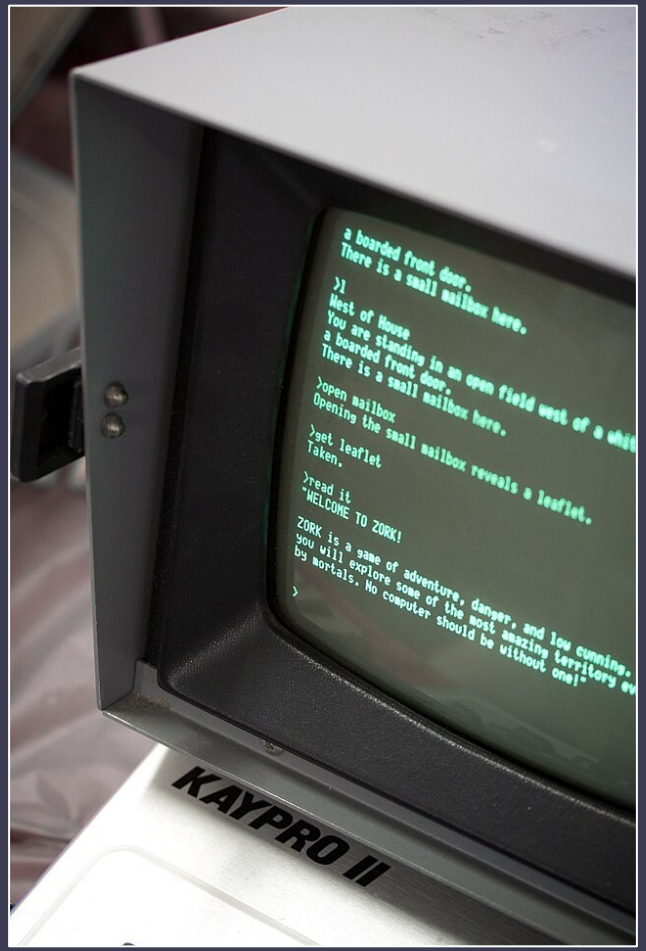
The path to Real Time path tracing

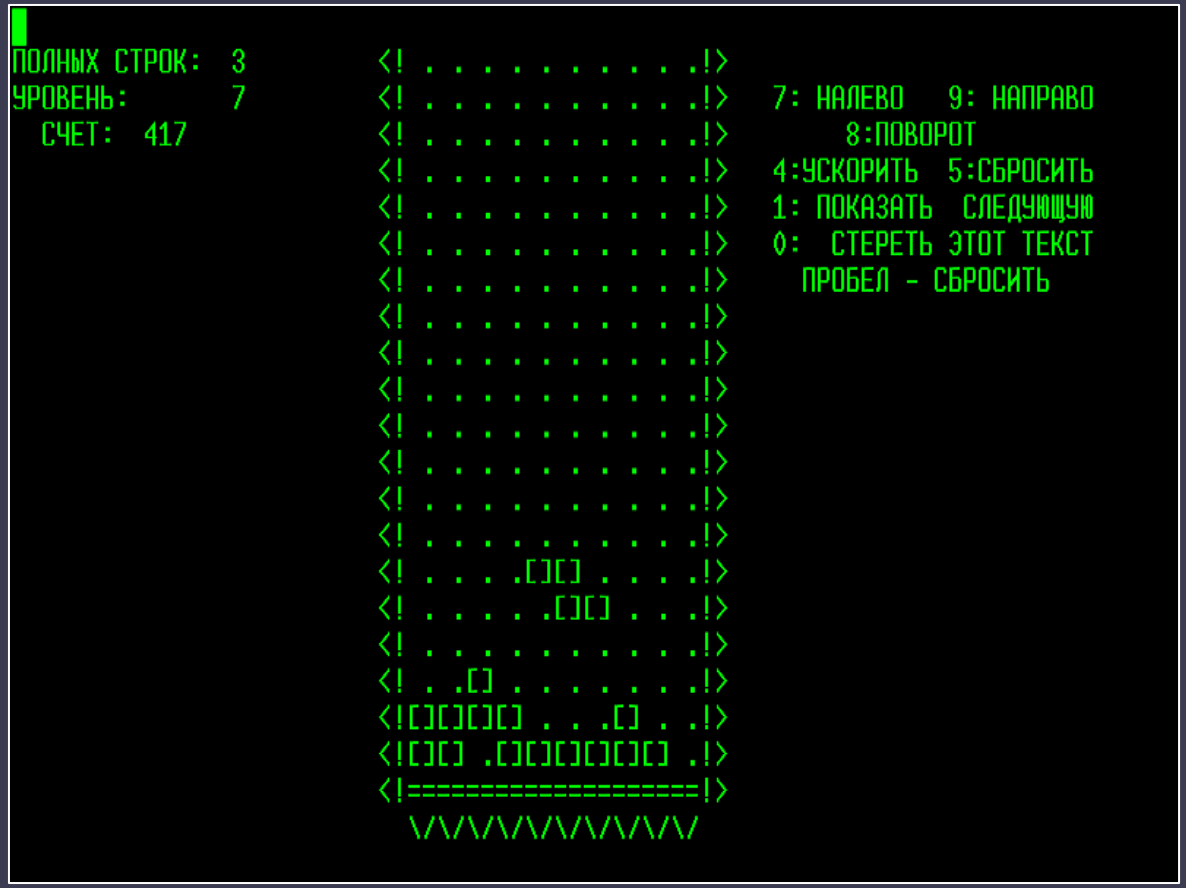
Vladislav Vulchev

Development Team Lead

The Beginning

CELTICS
9
HEAT
3
SIXERS
9
HEAT
6
BULLS
1
BULLS
23
SPURS
21
LAKERS
24
ORLANDO
12


a boarded front door.
There is a small mailbox here.
>l
West of House
You are standing in an open field west of a whit
a boarded front door.
There is a small mailbox here.
>open mailbox
Opening the small mailbox reveals a leaflet.
>get leaflet
Taken.
>read it
"WELCOME TO ZORK!
ZORK is a game of adventure, danger, and low cunning.
you will explore some of the most amazing territory ev
by mortals. No computer should be without one!"
>
KAYPRO II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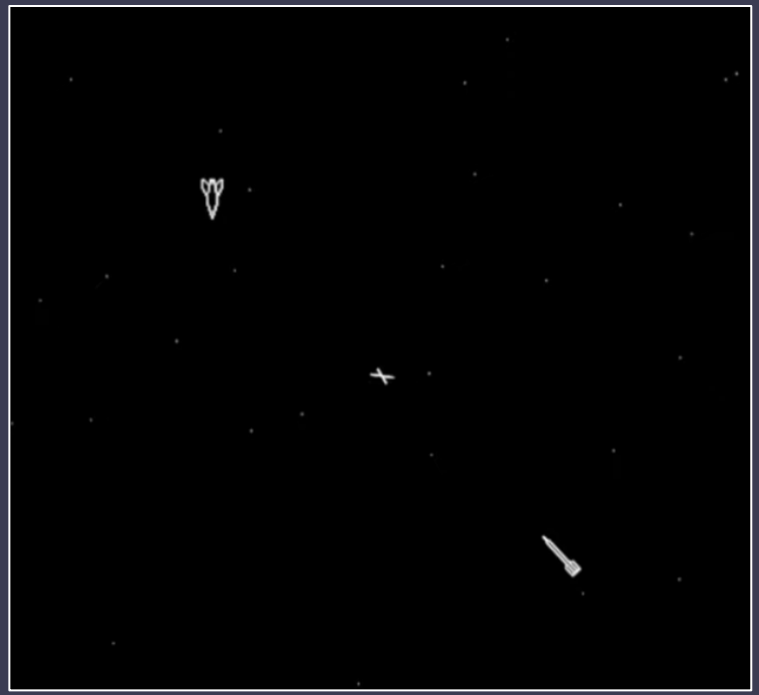
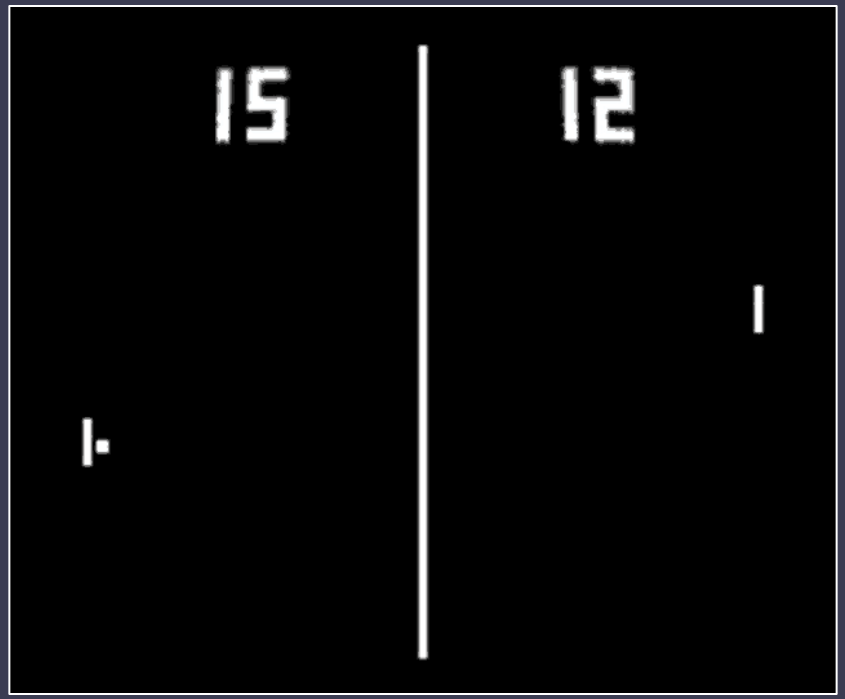
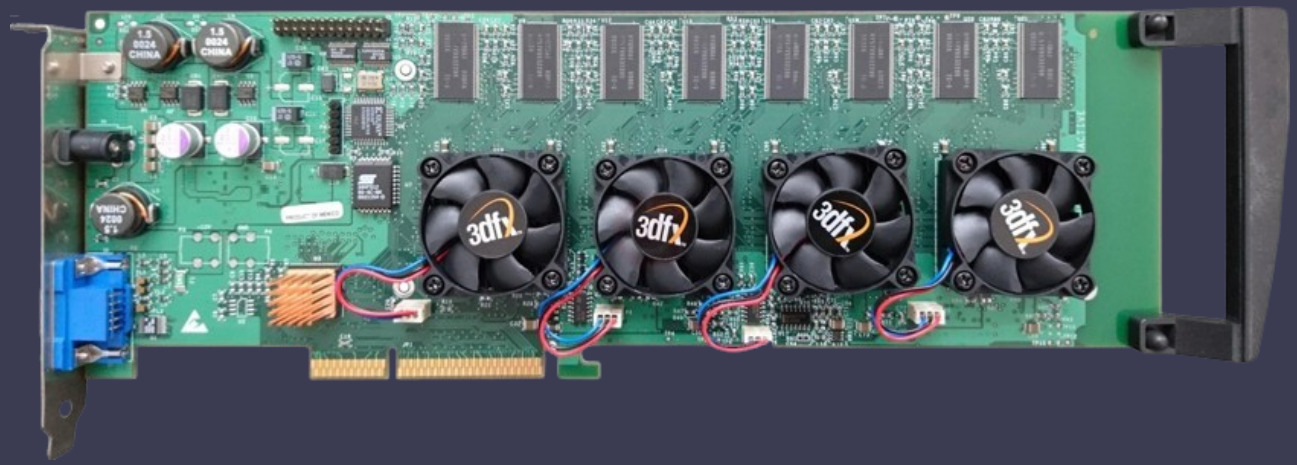
УРОВЕНЬ: 7
СЧЕТ: 417
7: НАЛЕВО 9: НАПРАВО
8:ПОВОРОТ
4:УСКОРИТЬ 5:СБРОСИТЬ
1: ПОКАЗАТЬ СЛЕДУЮЩУЮ
0: СТЕРЕТЬ ЭТОТ ТЕКСТ
ПРОБЕЛ - СБРОСИТЬ




15
12
1
1


3dfx
3dfx
3dfx
3dfx

92
133
2
0
139
97
92

Marlamin
85
Deathwing
<Aspect of Death>
Wetlands
11:00
General
[MikImage] has come online.
08:00 Deathwing yells: The sun has set on this mortal world, fools. Make peace with your end, for the hour of Twilight falls.

GTX 1080Ti

GTX 1080Ti

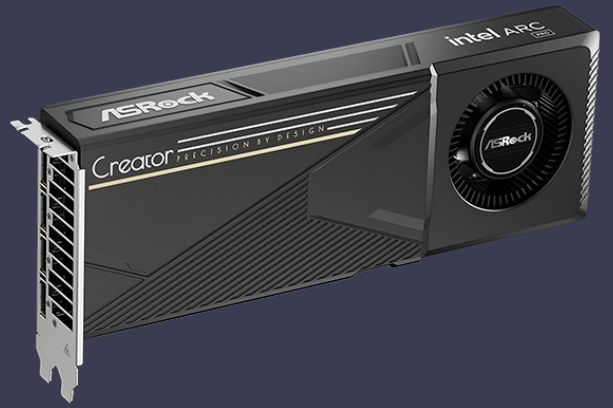
RTX 4090

GTX 1080Ti

GIGABYTE
AMD
RADEON
RX 9060 XT

RTX 4090

GTX 1080Ti

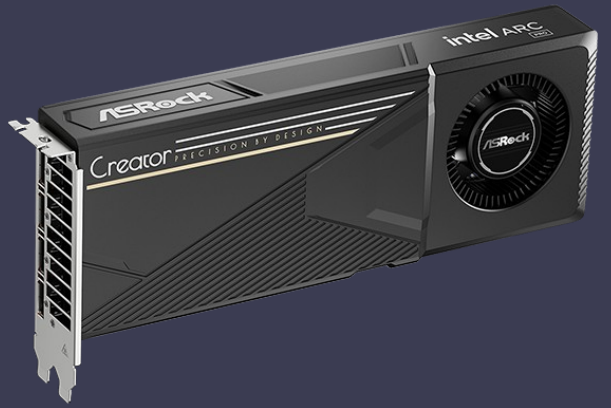

intel ARC
ASRock
Creator
PRECISION BY DESIGN
ASRock

GIGABYTE
GIGABYTE
AMD
RADEON
RX 9060 XT
GIGABYTE
AMD
RADEON
RX 9060 XT

RTX 4090

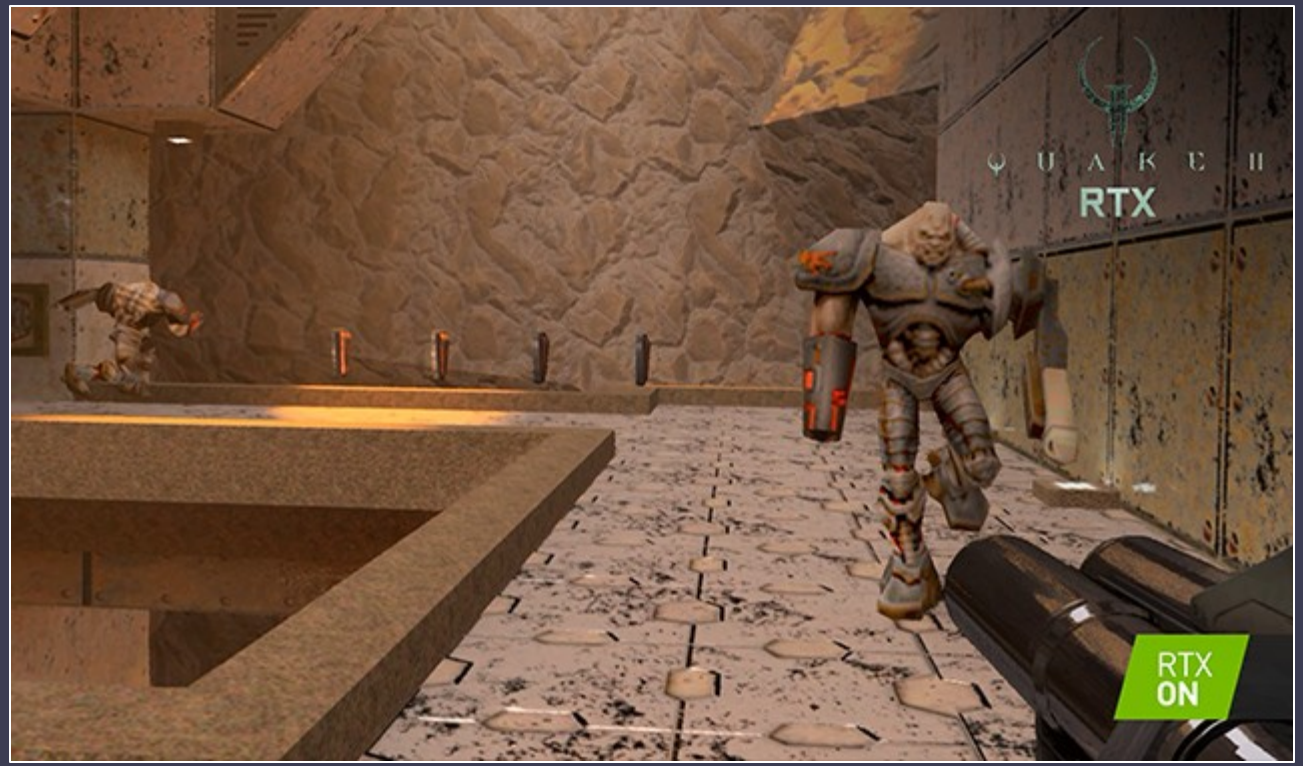
GTX 1080Ti

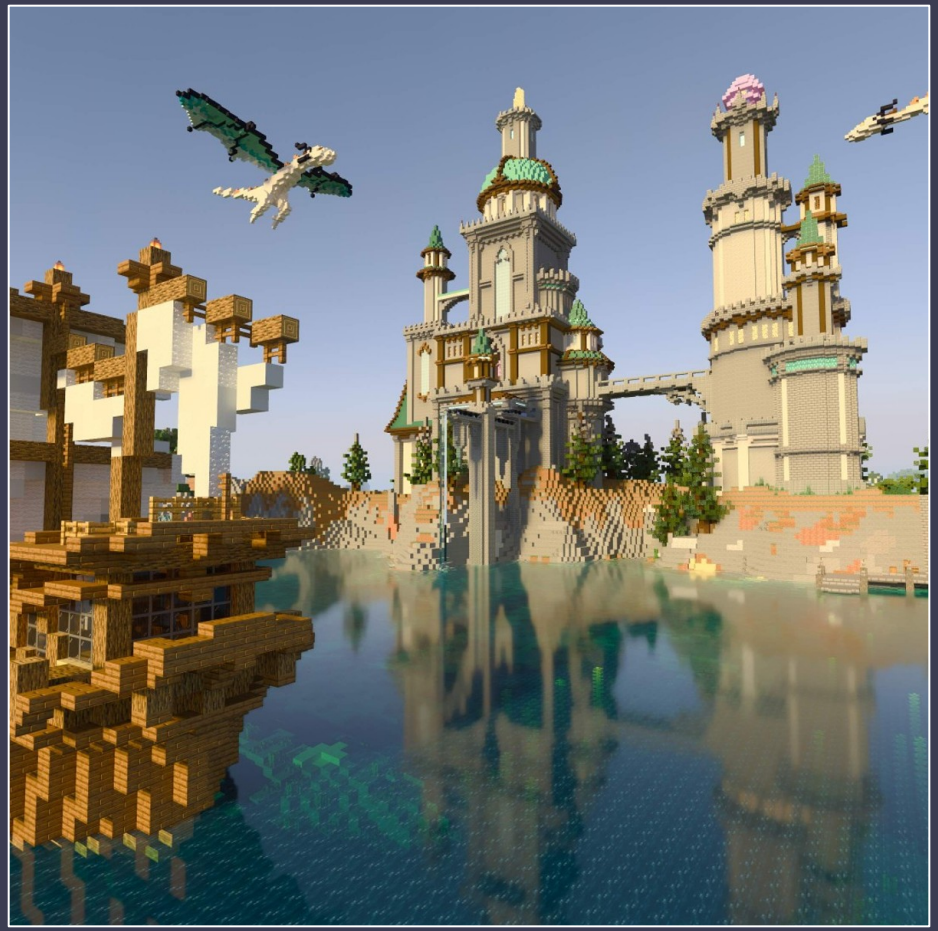
RTX 5090
GEFORCE RTX


ASRock
Creator
PRECISION BY DESIGN
intel ARC

GIGABYTE
AMD
RADEON
RX 9060 XT
GAMING OC

RTX 4090


QUAKE II
RTX
RTX
ON



Walt Disney Pictures
presents
TOY
STORY

DreamWorks
HOW TO TRAIN YOUR
DRAGON
3D

Disney · PIXAR
ONWARD
Valor

Graphics Programming Conference, November 18-20, Breda

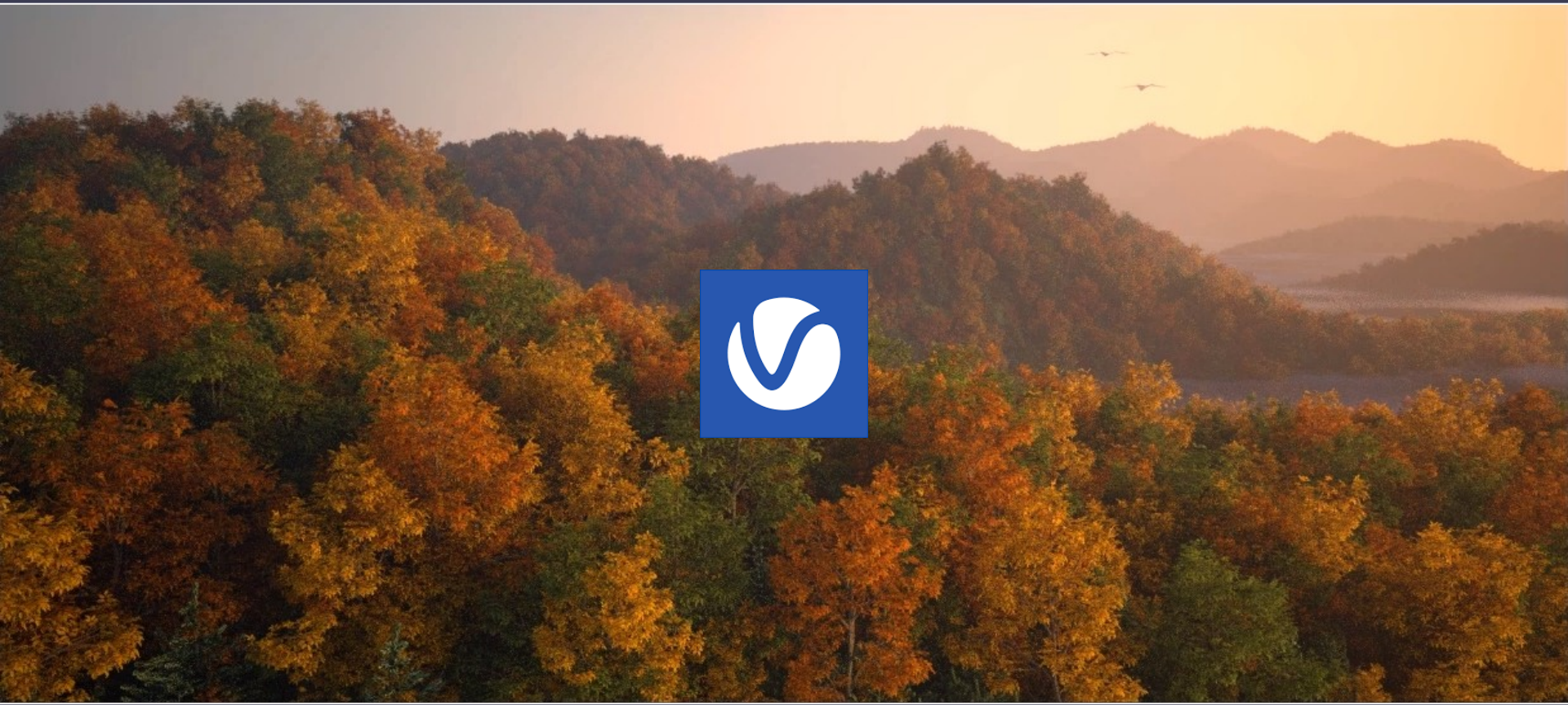
2025

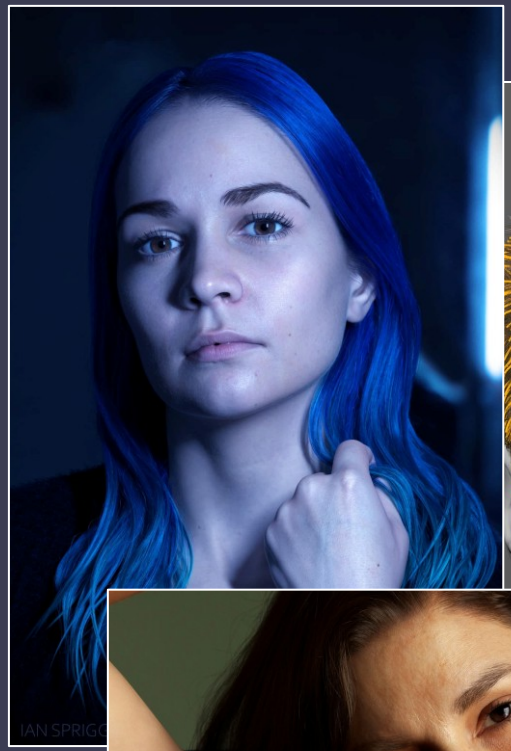
chaos

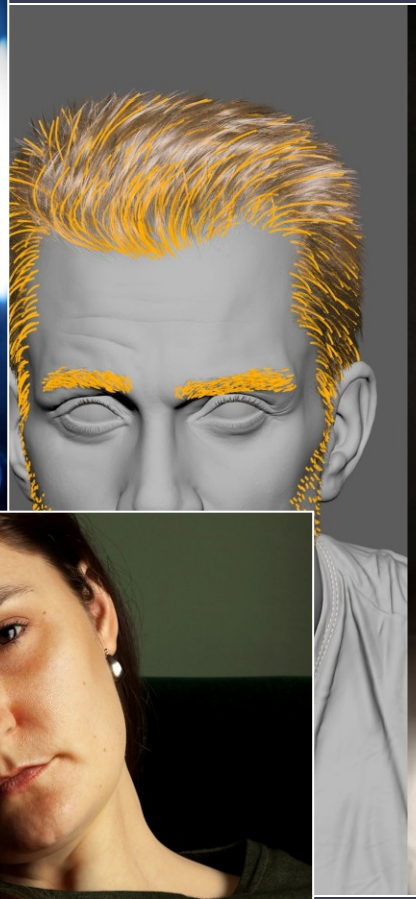
chaos

Photorealism

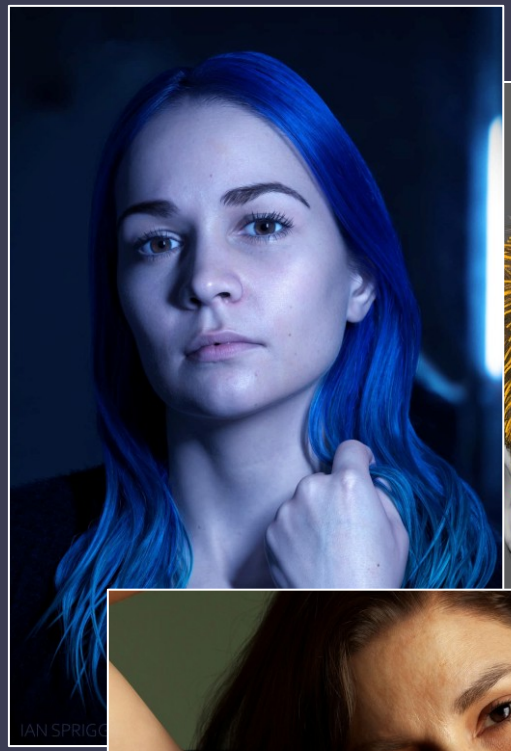
C++

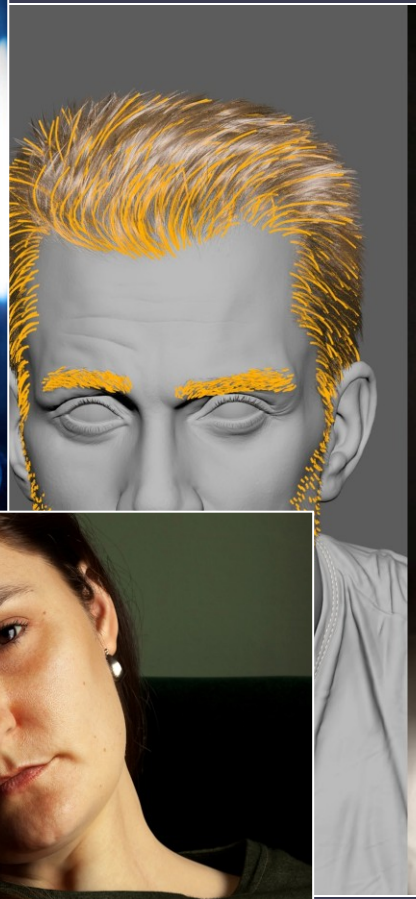



IAN SPRIGGS



IAN SPRIGGS


IAN SPRIGGS



IAN SPRIGGS

March 2002

March 2002

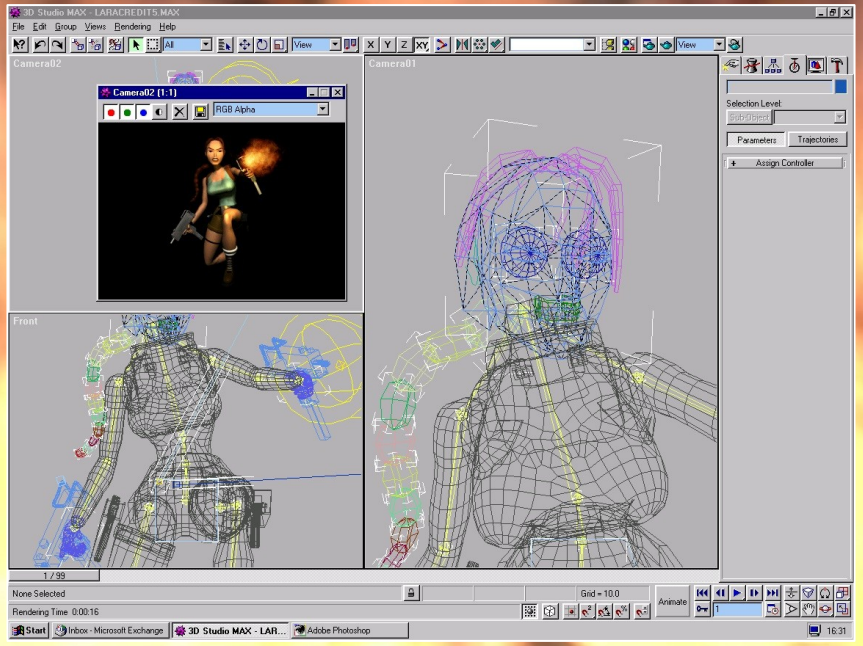
1997

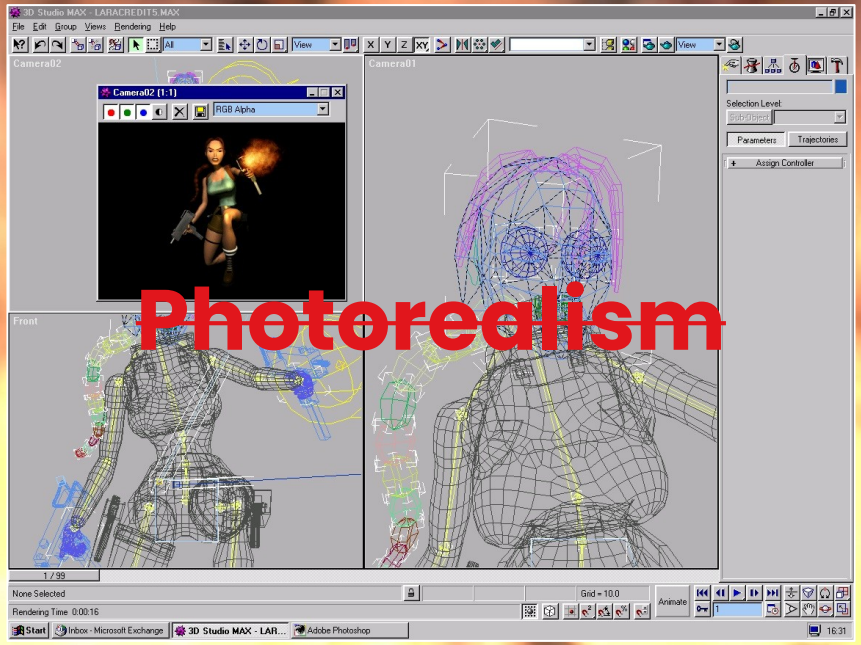
1997

© A.M.P.A.S.

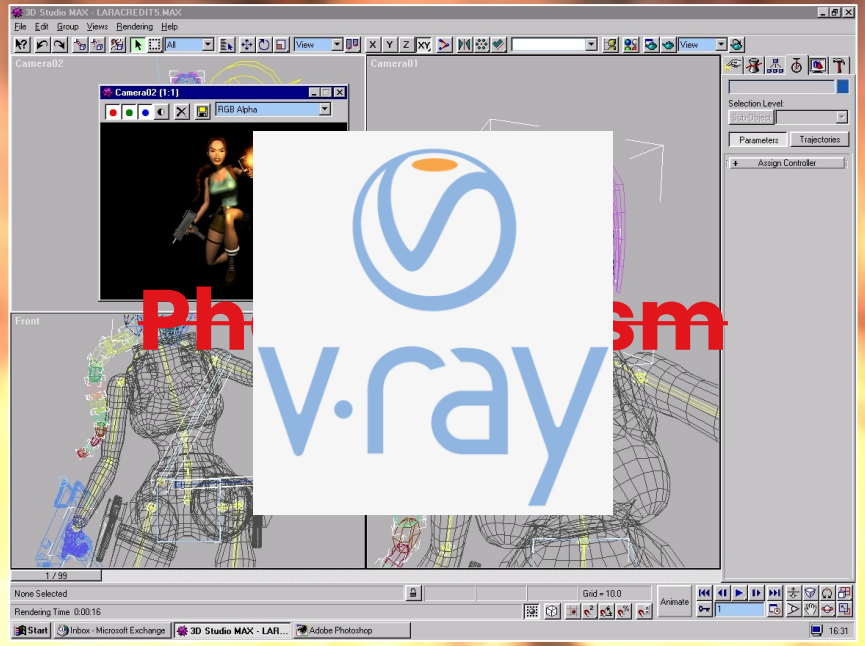
1998

Phoenix
1998


3D Studio MAX - LARACREDITS.MAX
File Edit Group Views Rendering Help
Camera02
Camera02 (1:1)
RGB Alpha
Camera01
Front
Selection Level:
Parameters
Trajectories
Assign Controller
1 / 99
None Selected
Grid = 10.0
Rendering Time 0:00:16
Animate
Start
Inbox - Microsoft Exchange
3D Studio MAX - LAR...
Adobe Photoshop
16:31



Photorealism


3D Studio MAX - LARACREDITS.MAX
File Edit Group Views Rendering Help
Camera02
Camera01
Camera02 (1:1)
RGB Alpha
Front
Selection Level:
Parameters
Trajectories
Assign Controller
1 / 99
None Selected
Grid = 10.0
Rendering Time 0:00:16
Animate
Start
Inbox - Microsoft Exchange
3D Studio MAX - LAR...
Adobe Photoshop
16:31
v-ray

Gigantic meshes

Gigantic meshes

Global Illumination

Gigantic meshes

Global Illumination

Reflections

Refractions

Gigantic meshes

Global Illumination

Reflections

Refractions

Nice/Soft Shadows

Gigantic meshes

Global Illumination

Reflections

Refractions

Nice/Soft Shadows

Complex materials

Complex textures

Gigantic meshes

Global Illumination

Reflections

Refractions

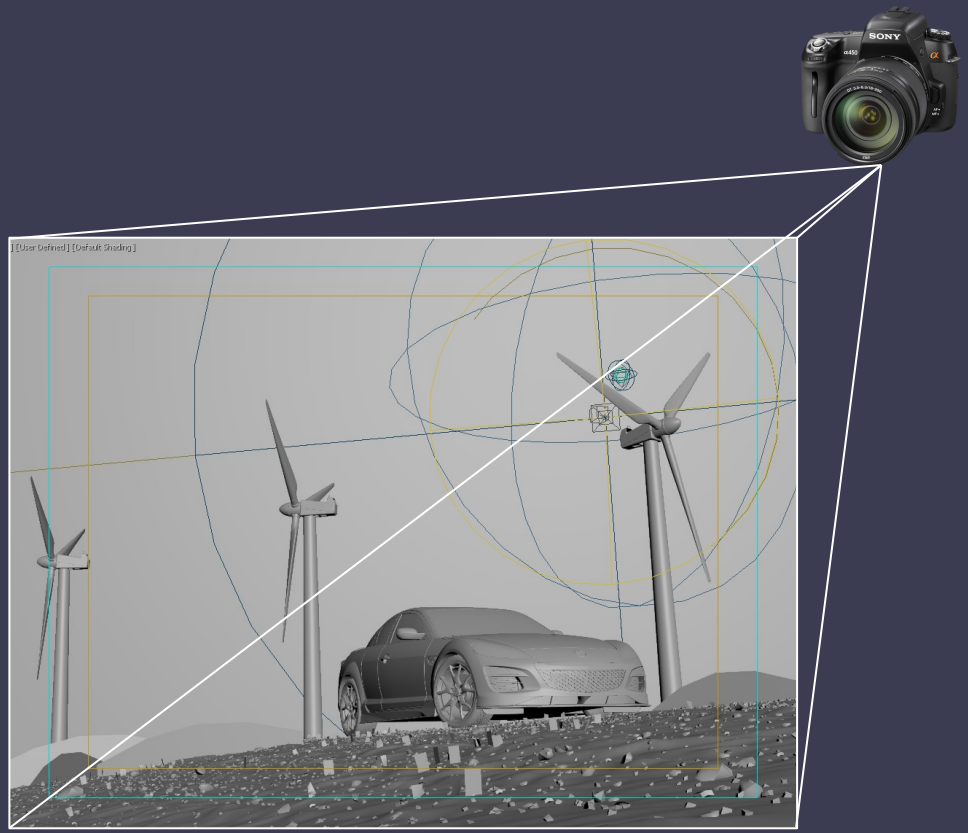
Nice/Soft Shadows

Complex materials

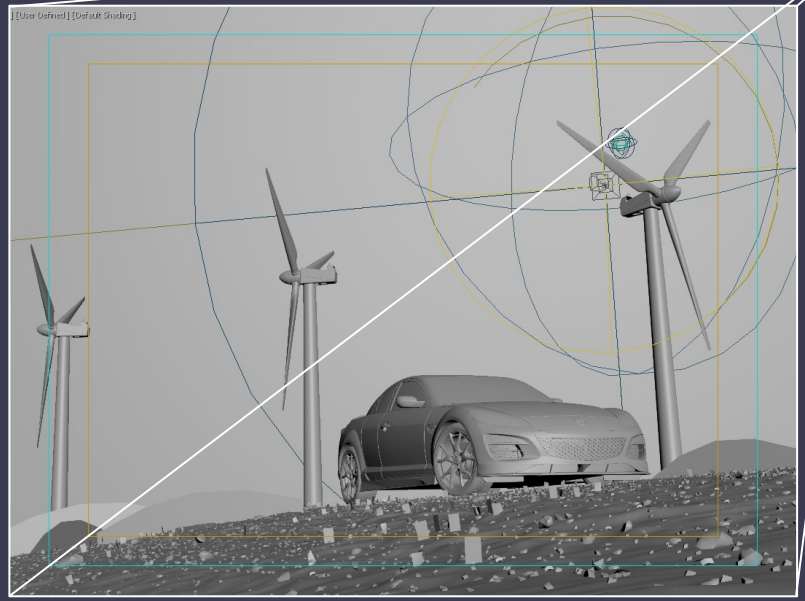
Complex textures

...

SONY
α450
DT 3.5-6.3/18-250
AF
MF


SONY

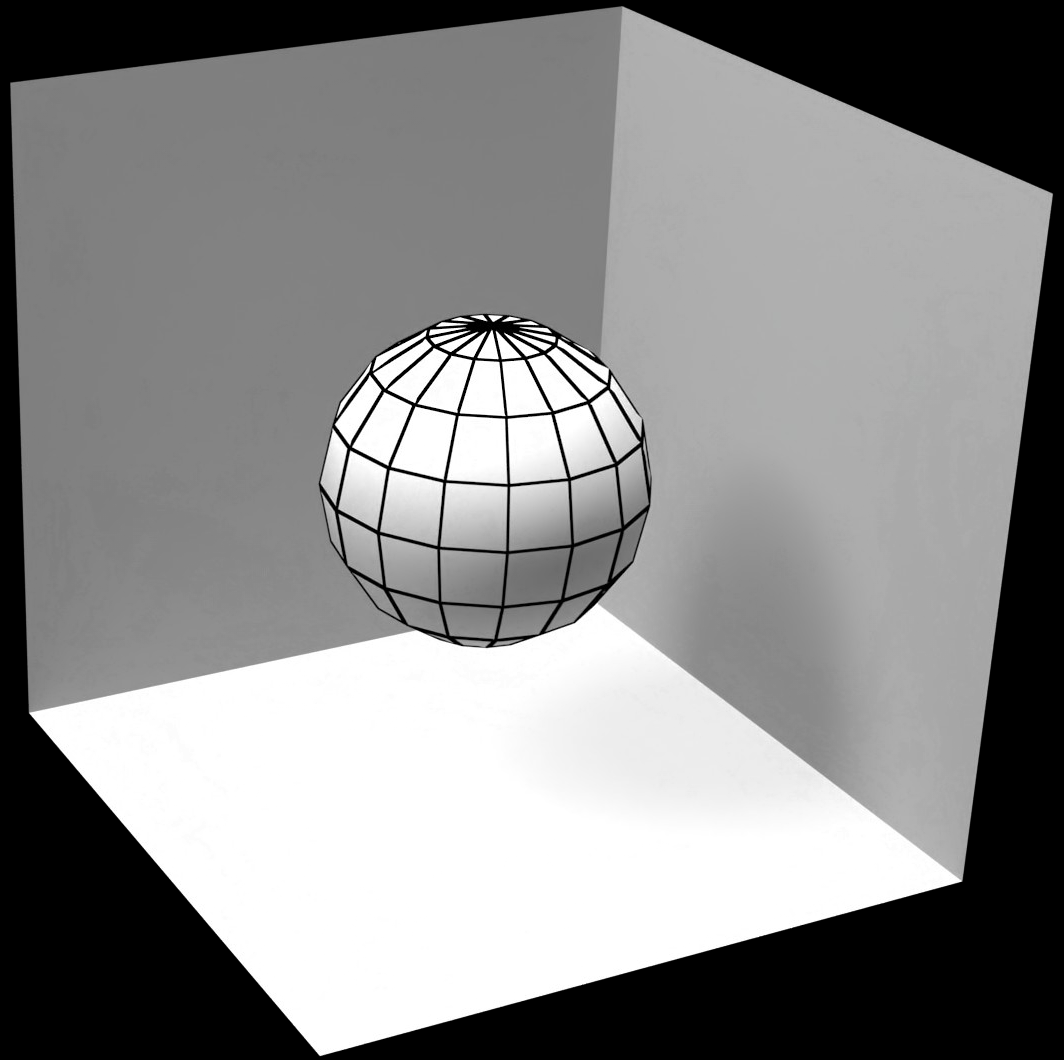
SONY

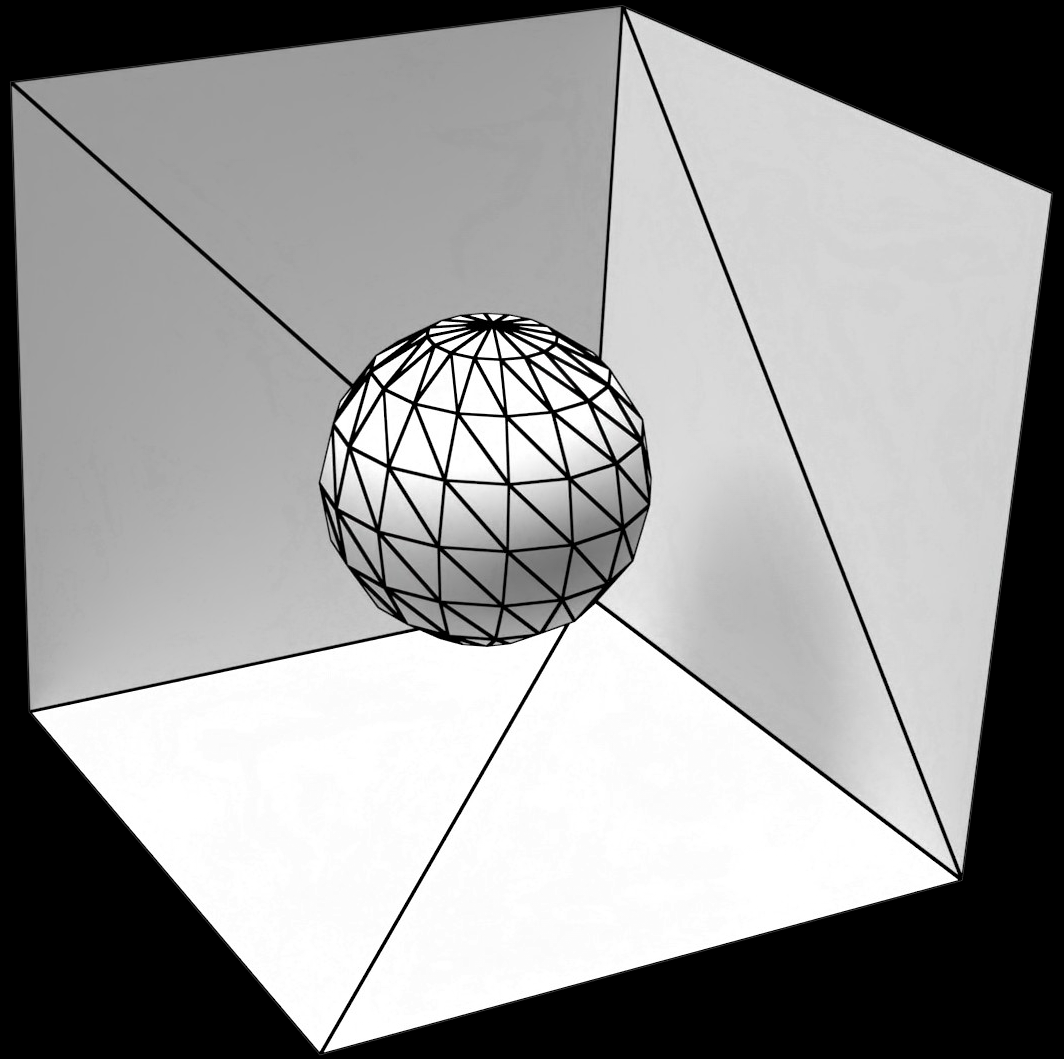


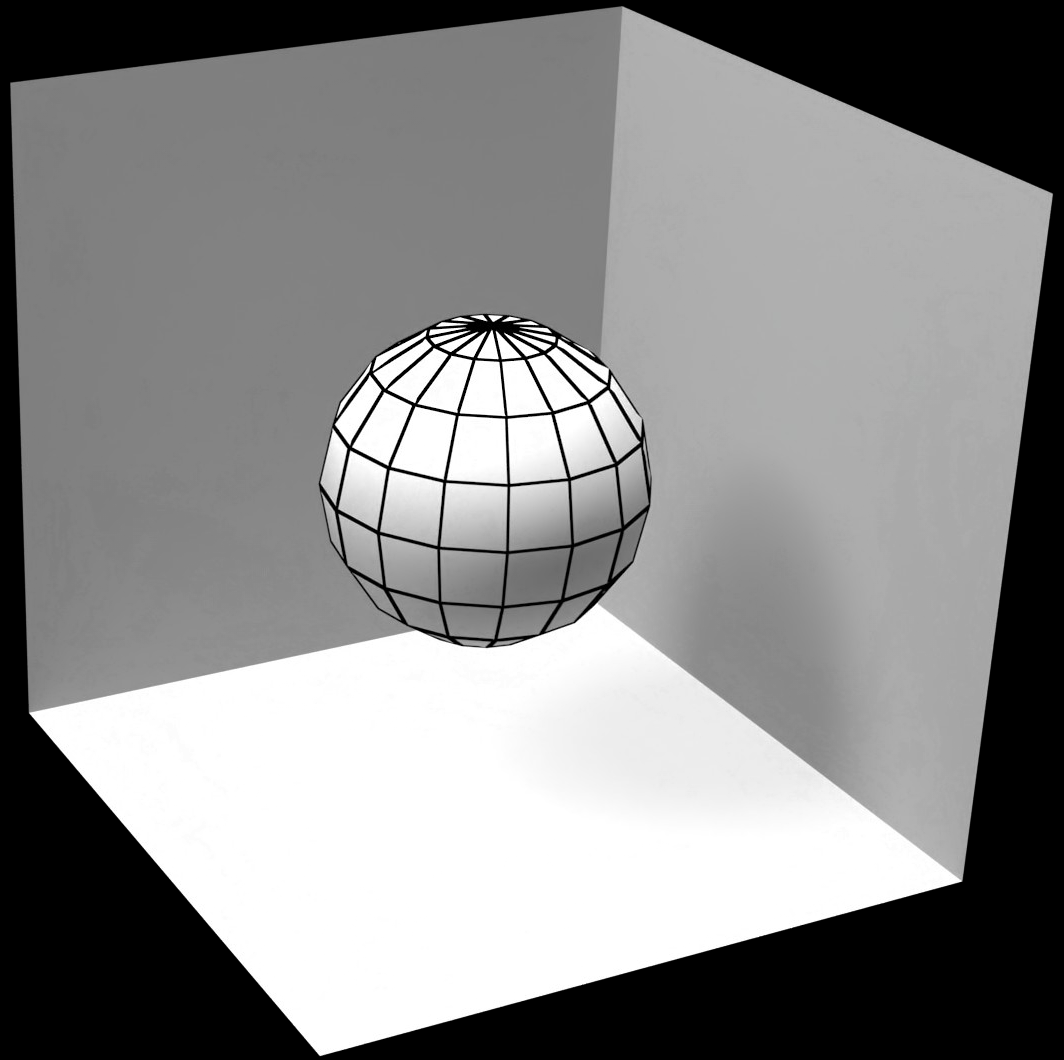
Rays

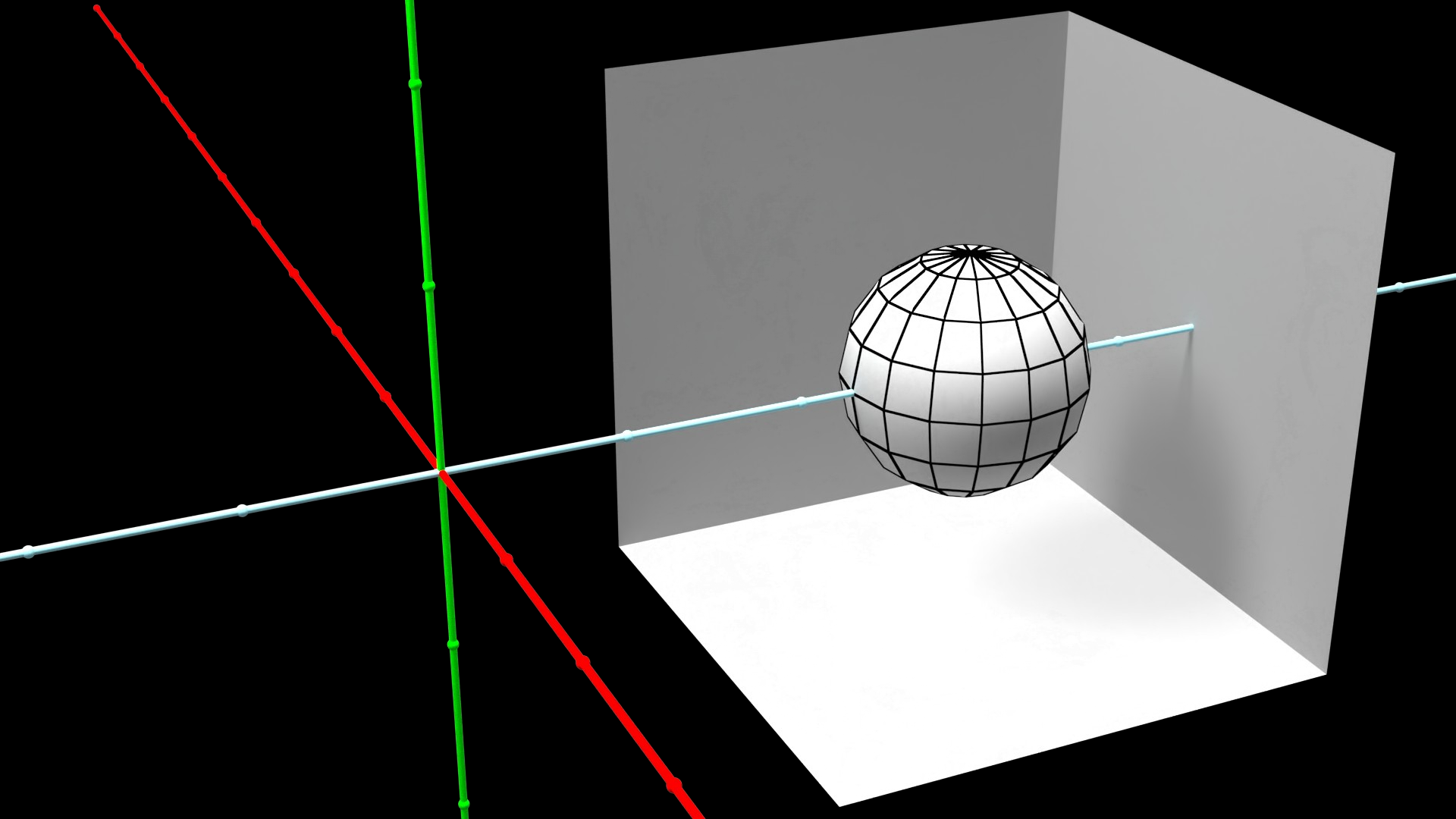
Trace Rays

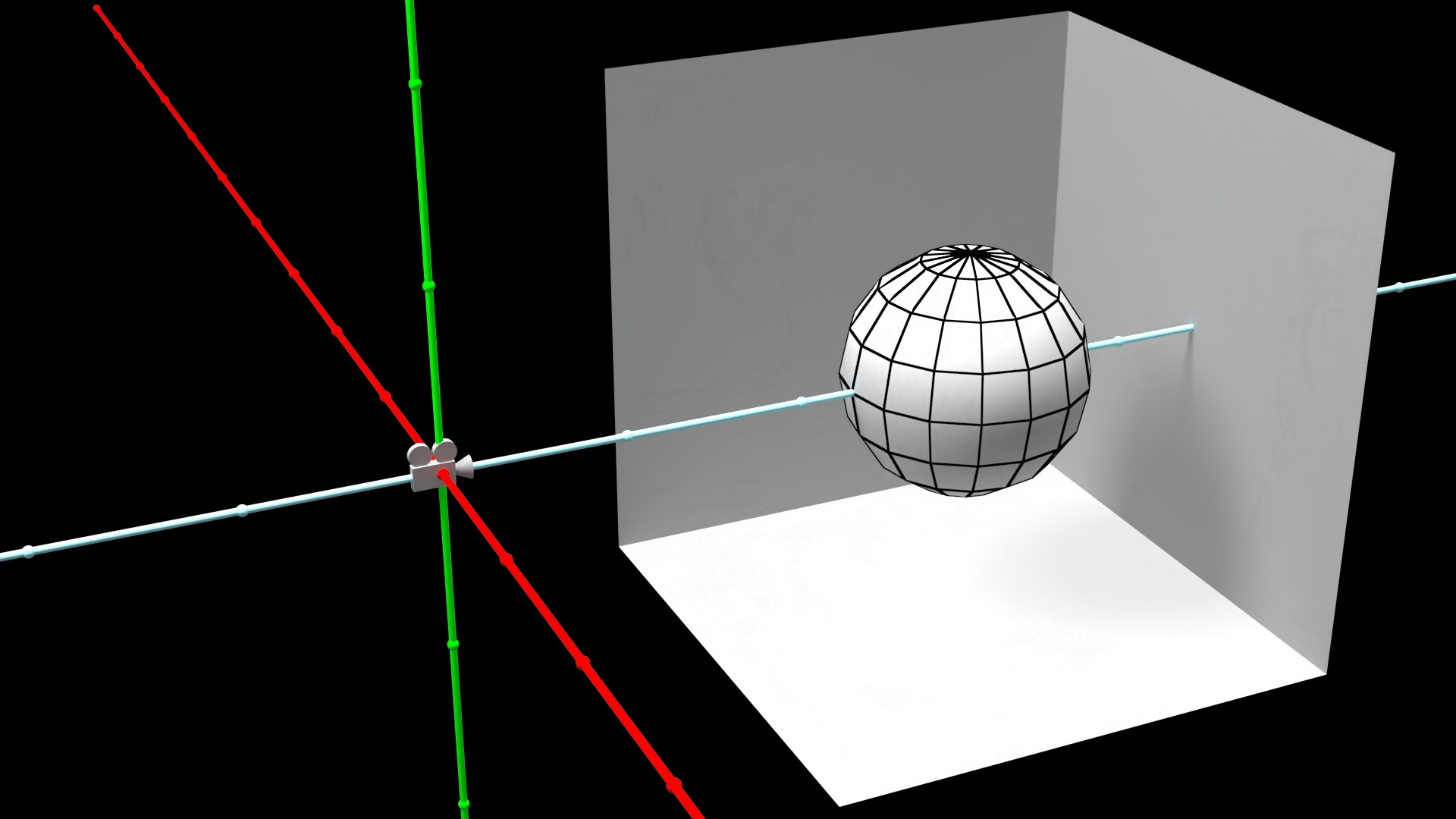
Path Tracing

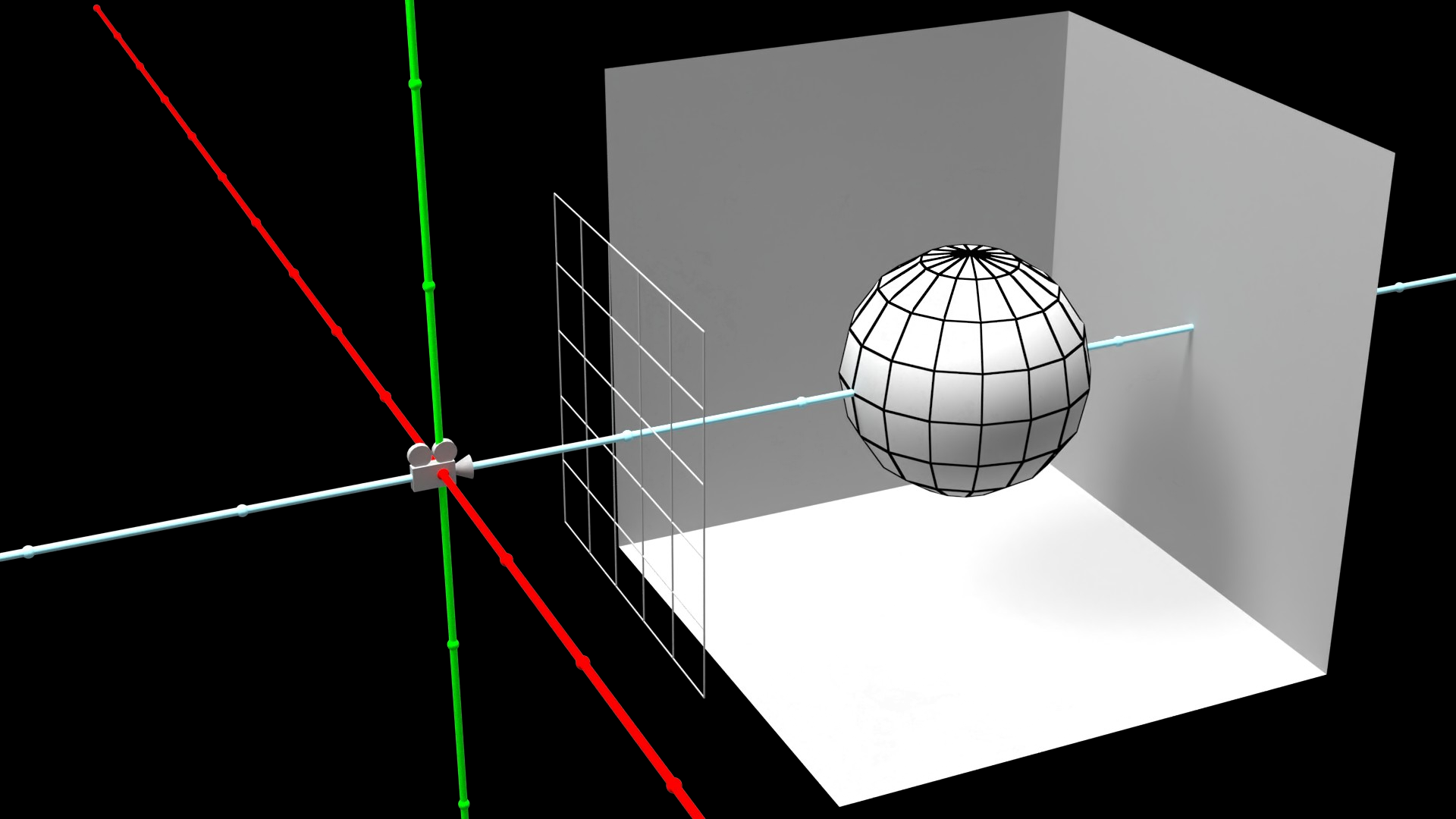


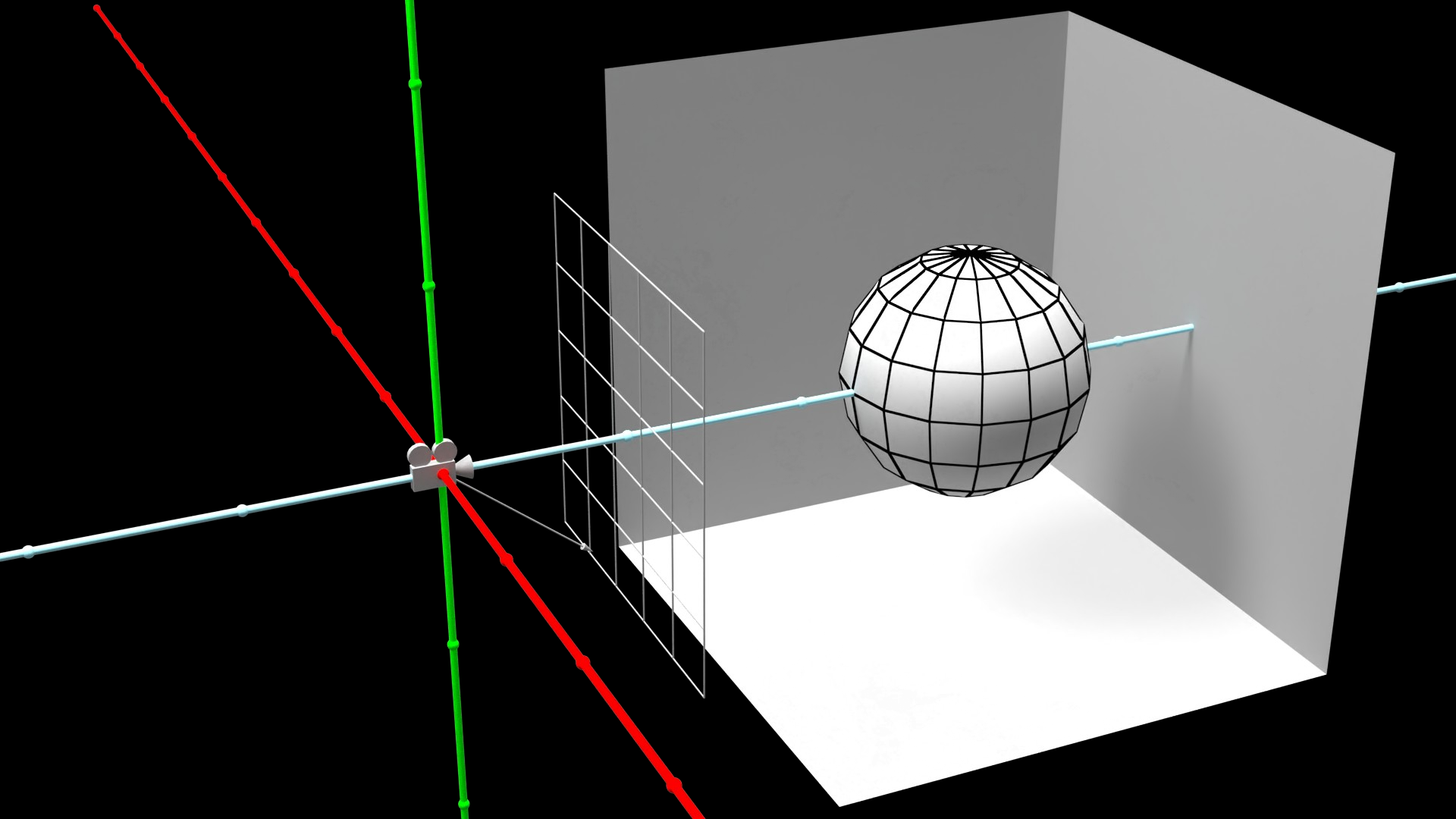


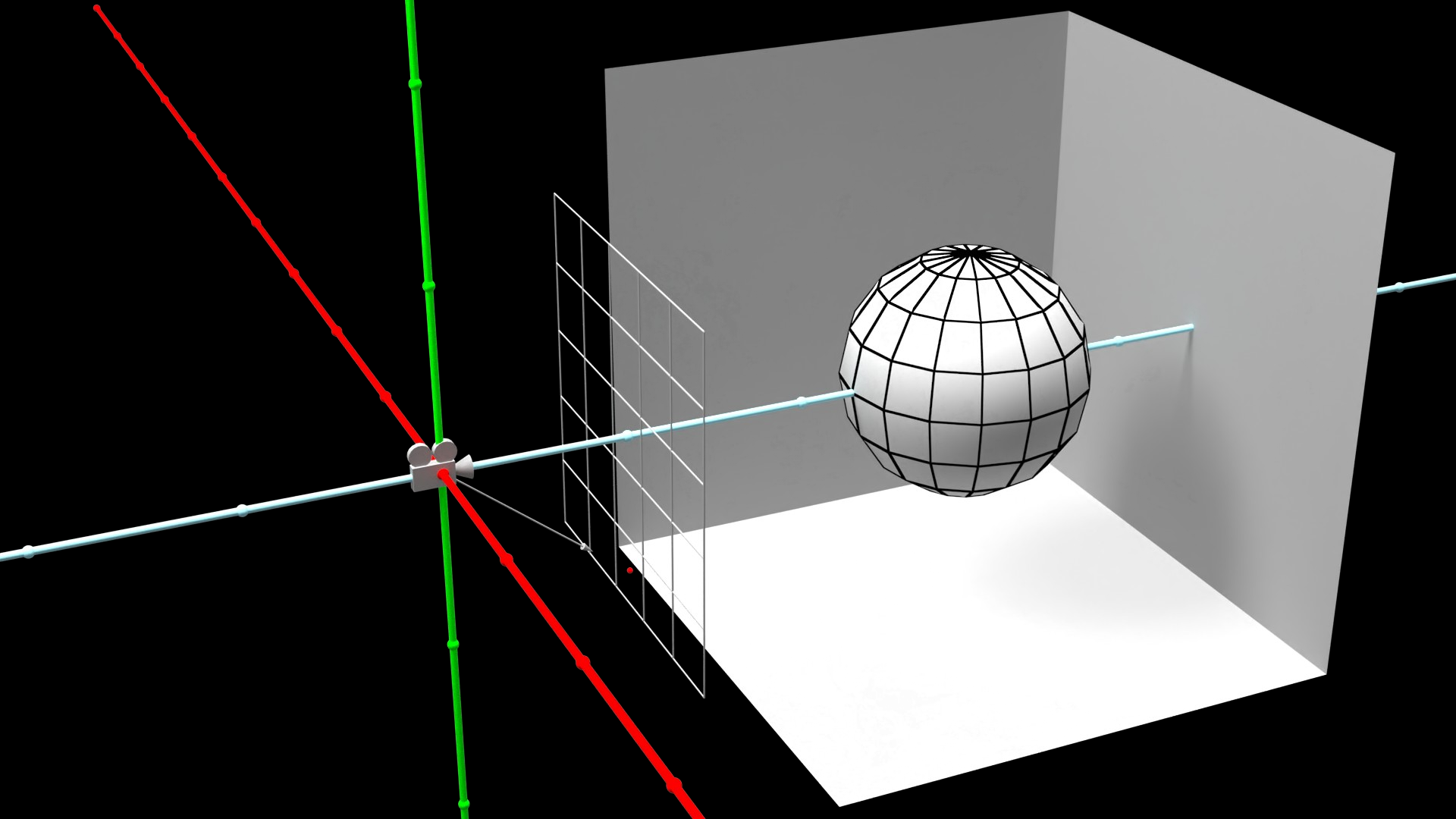


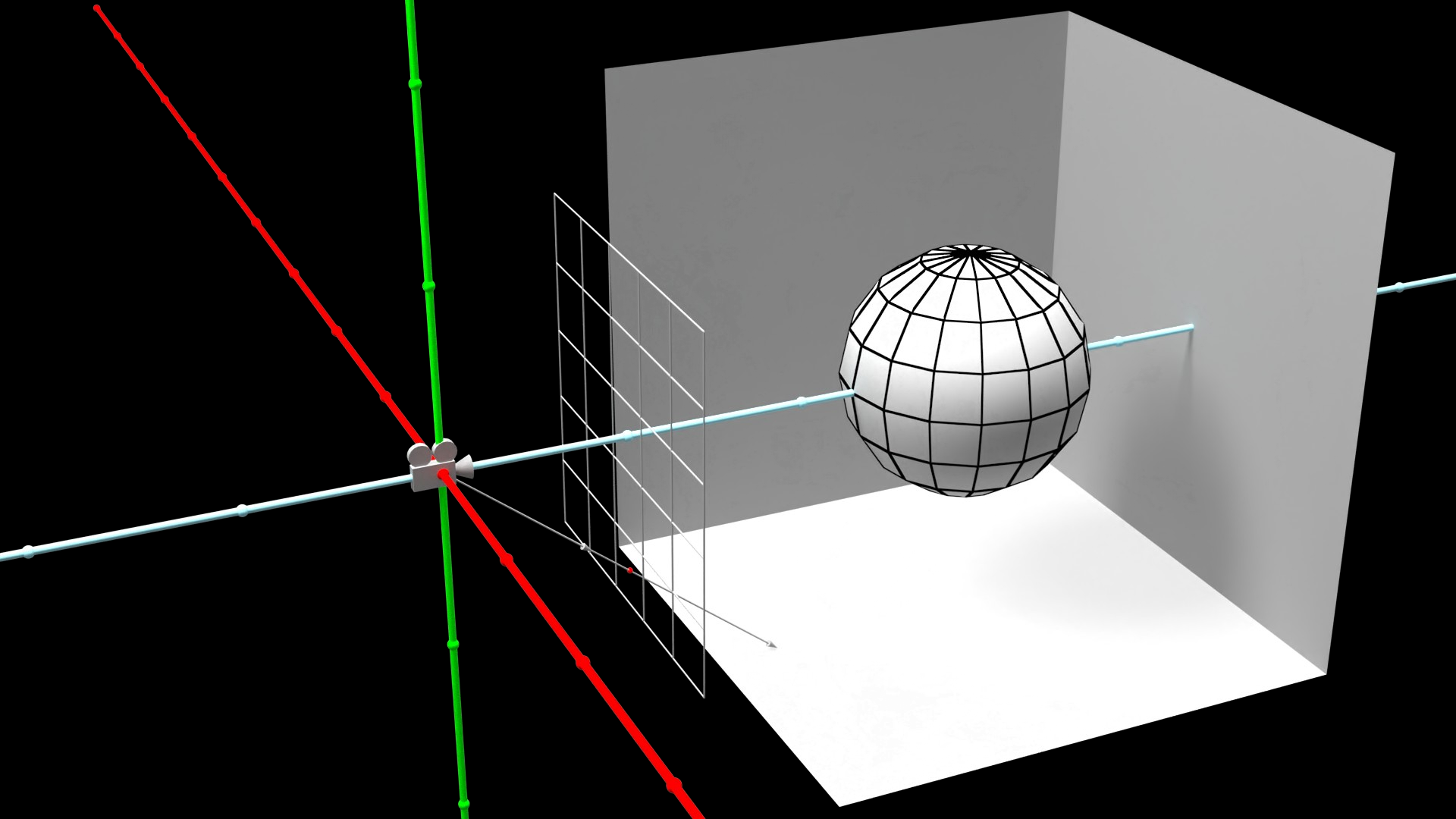


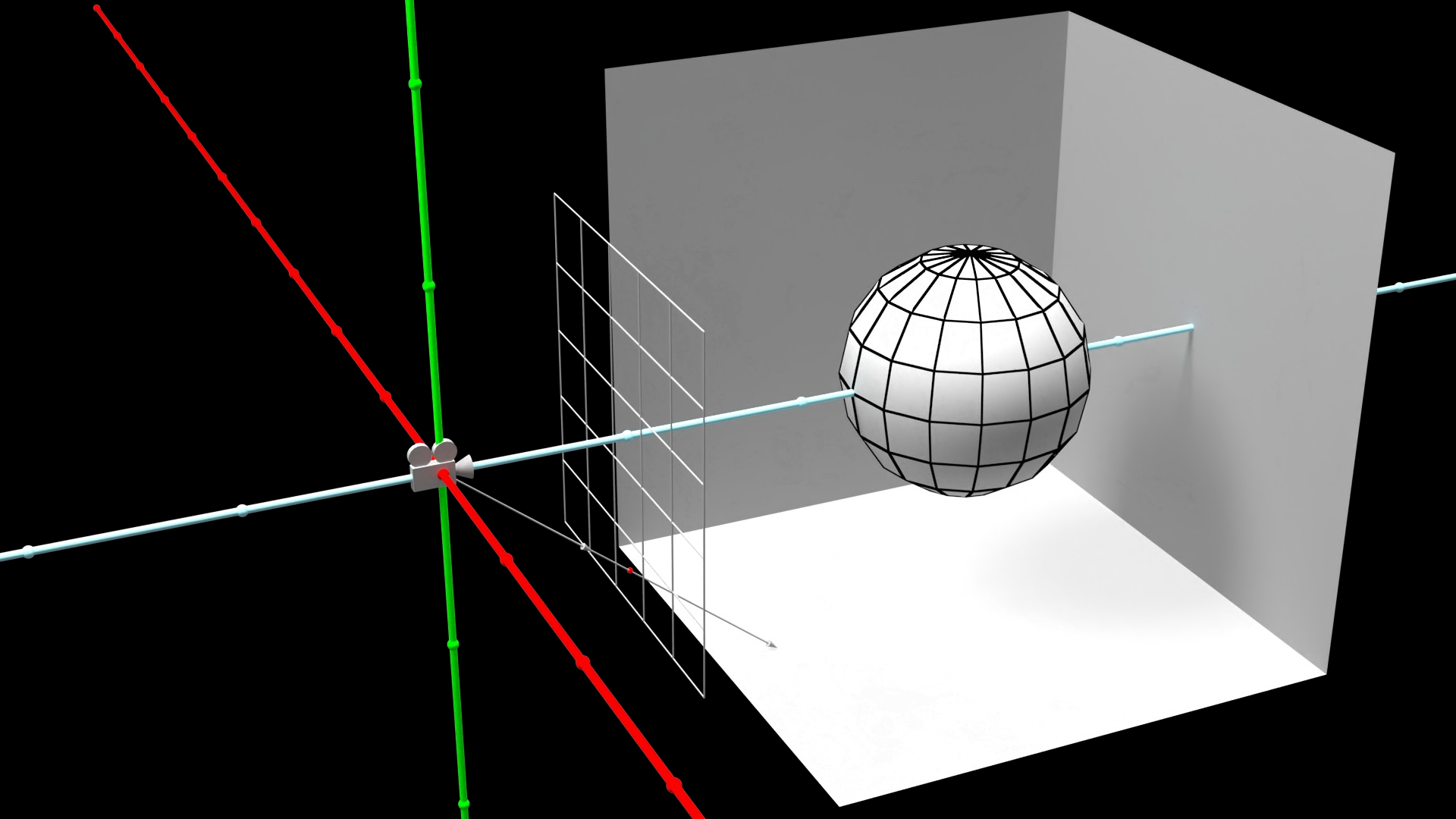


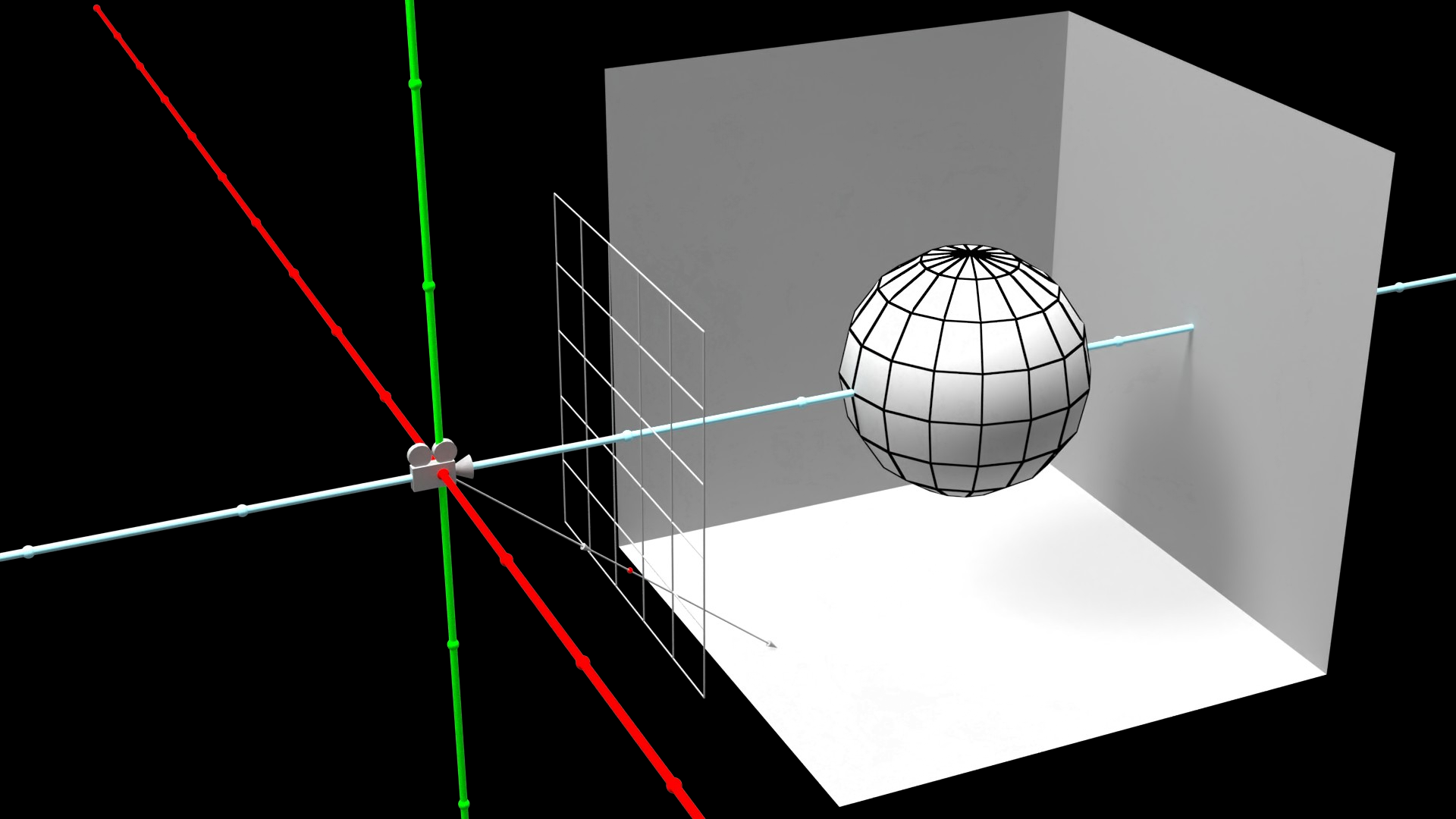


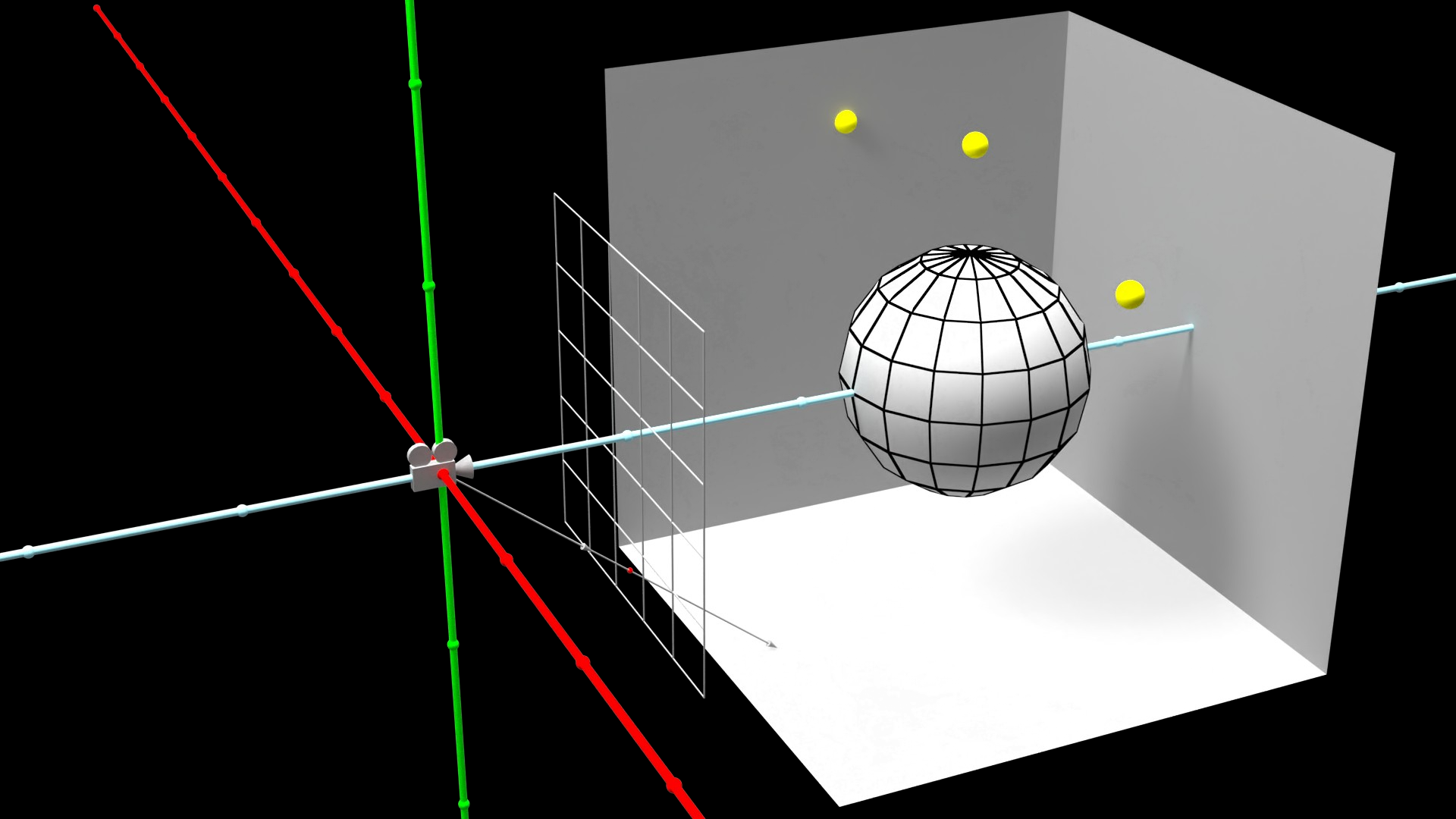


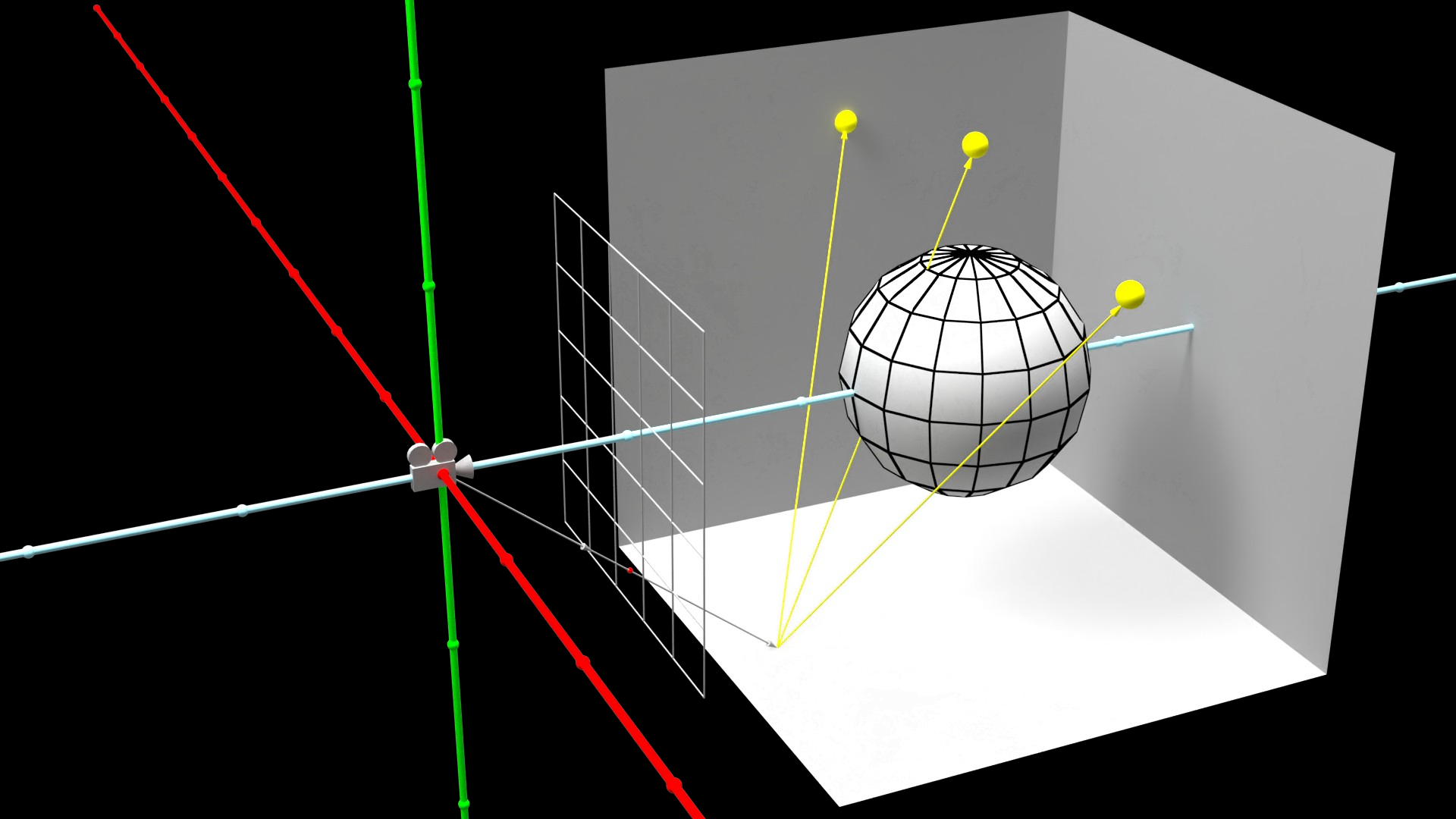


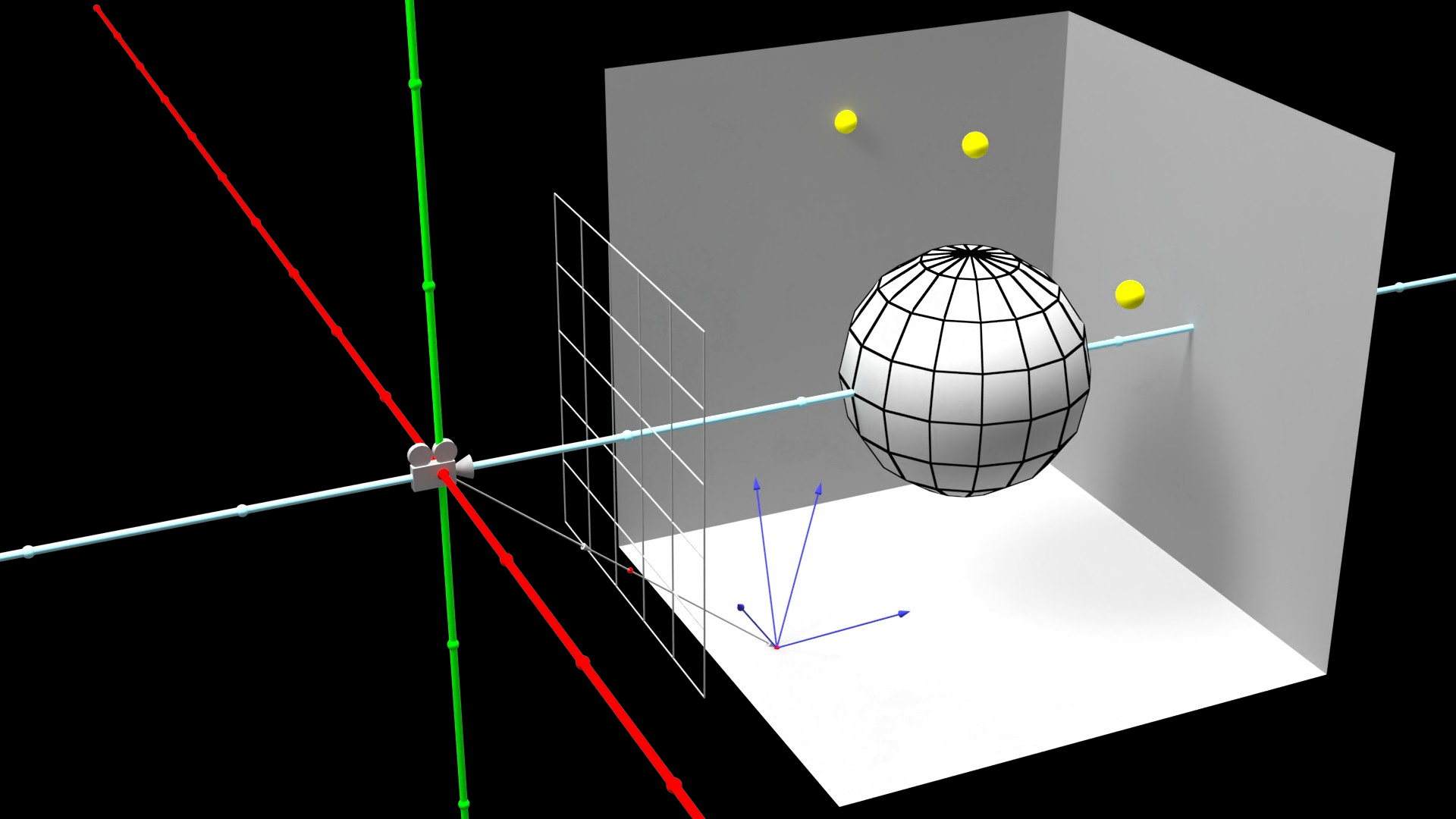


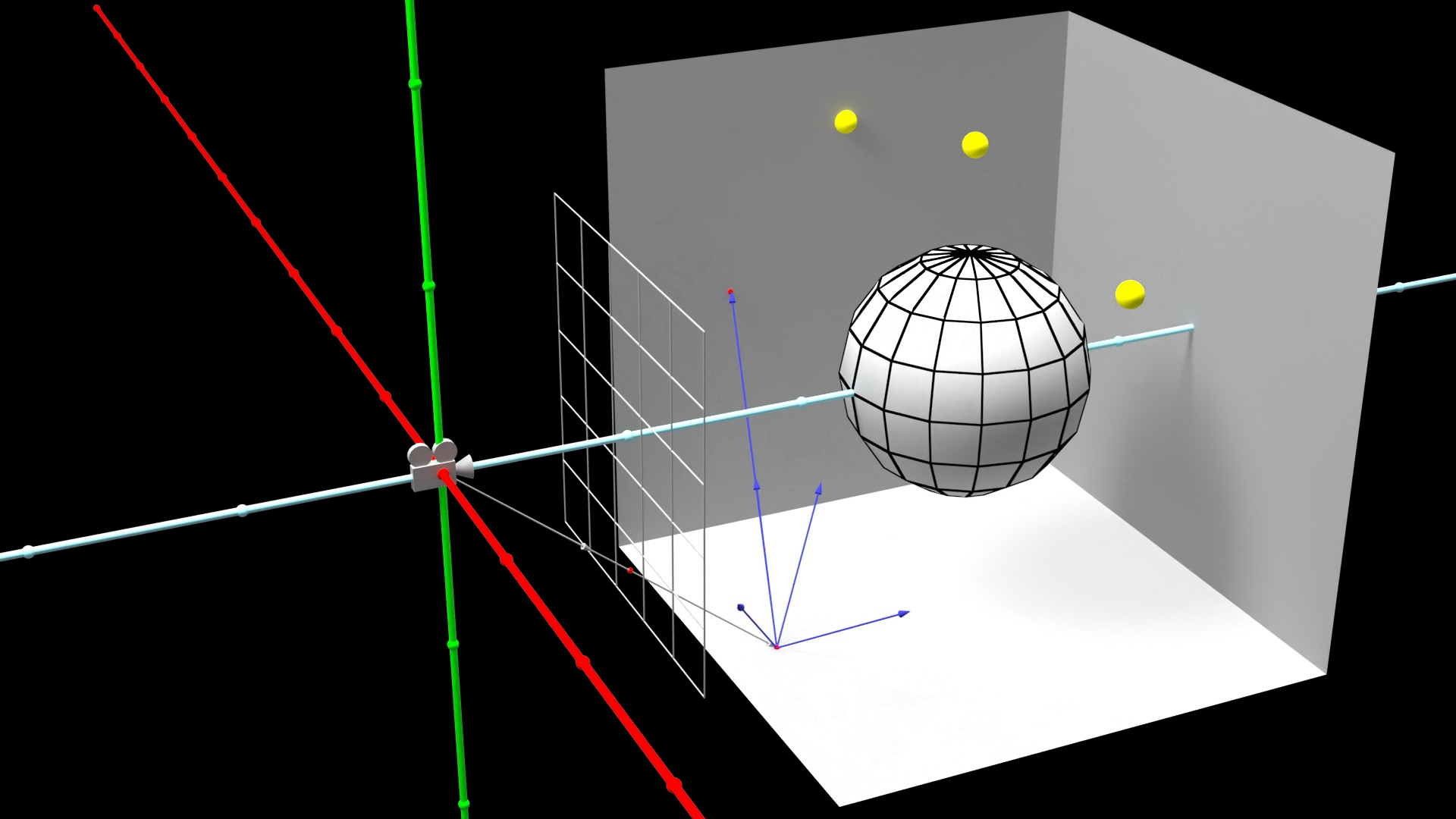


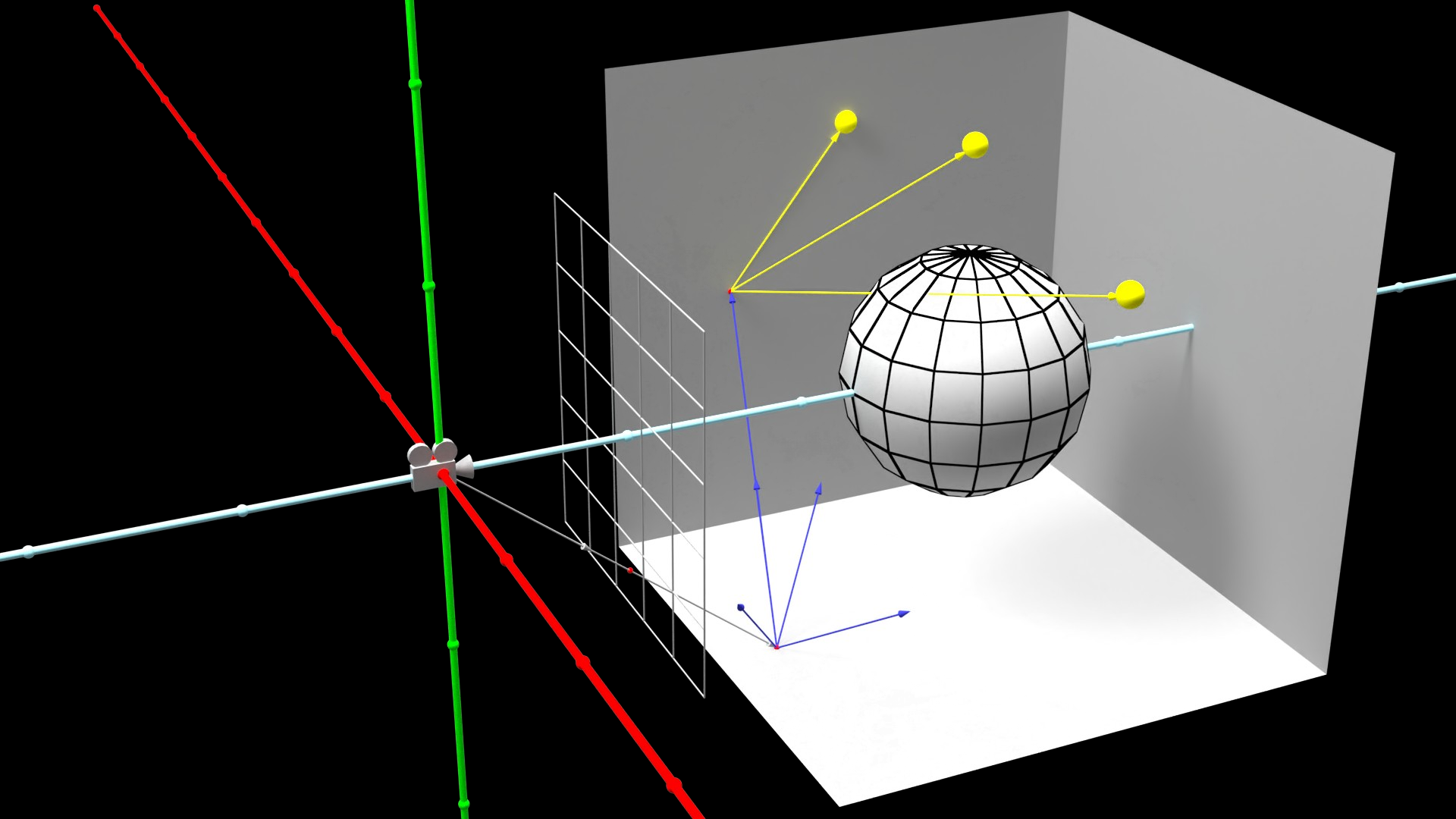


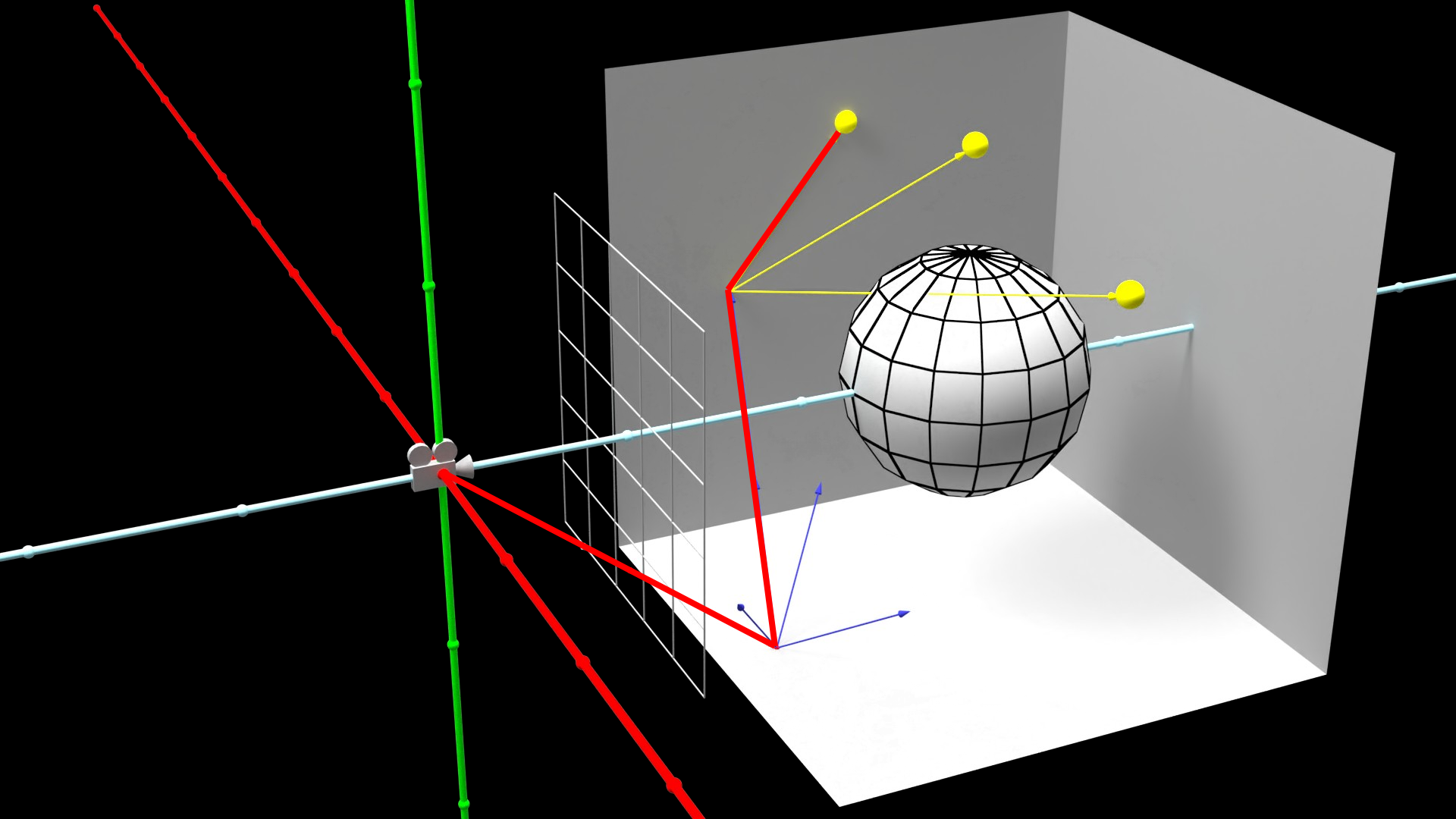


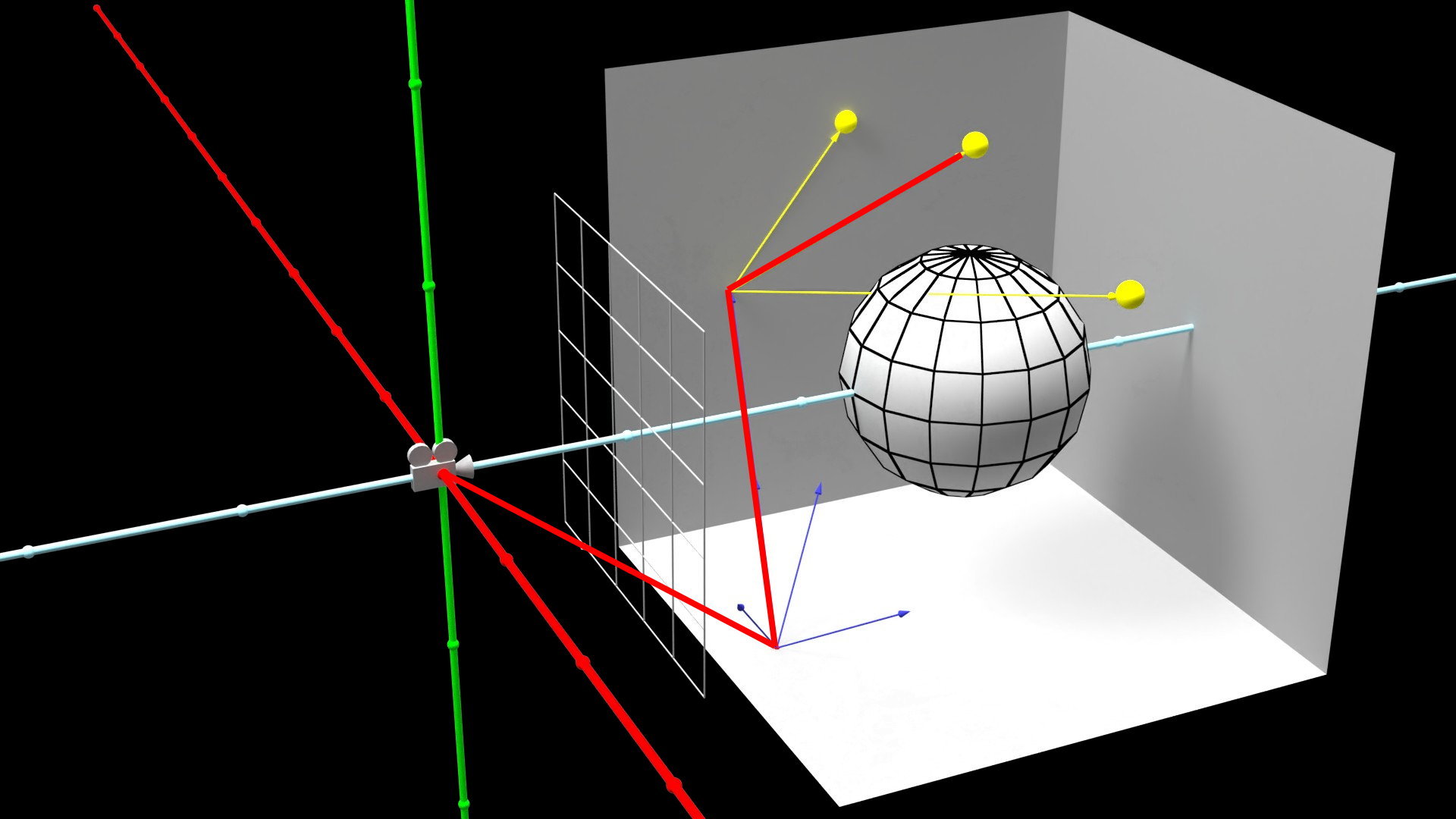


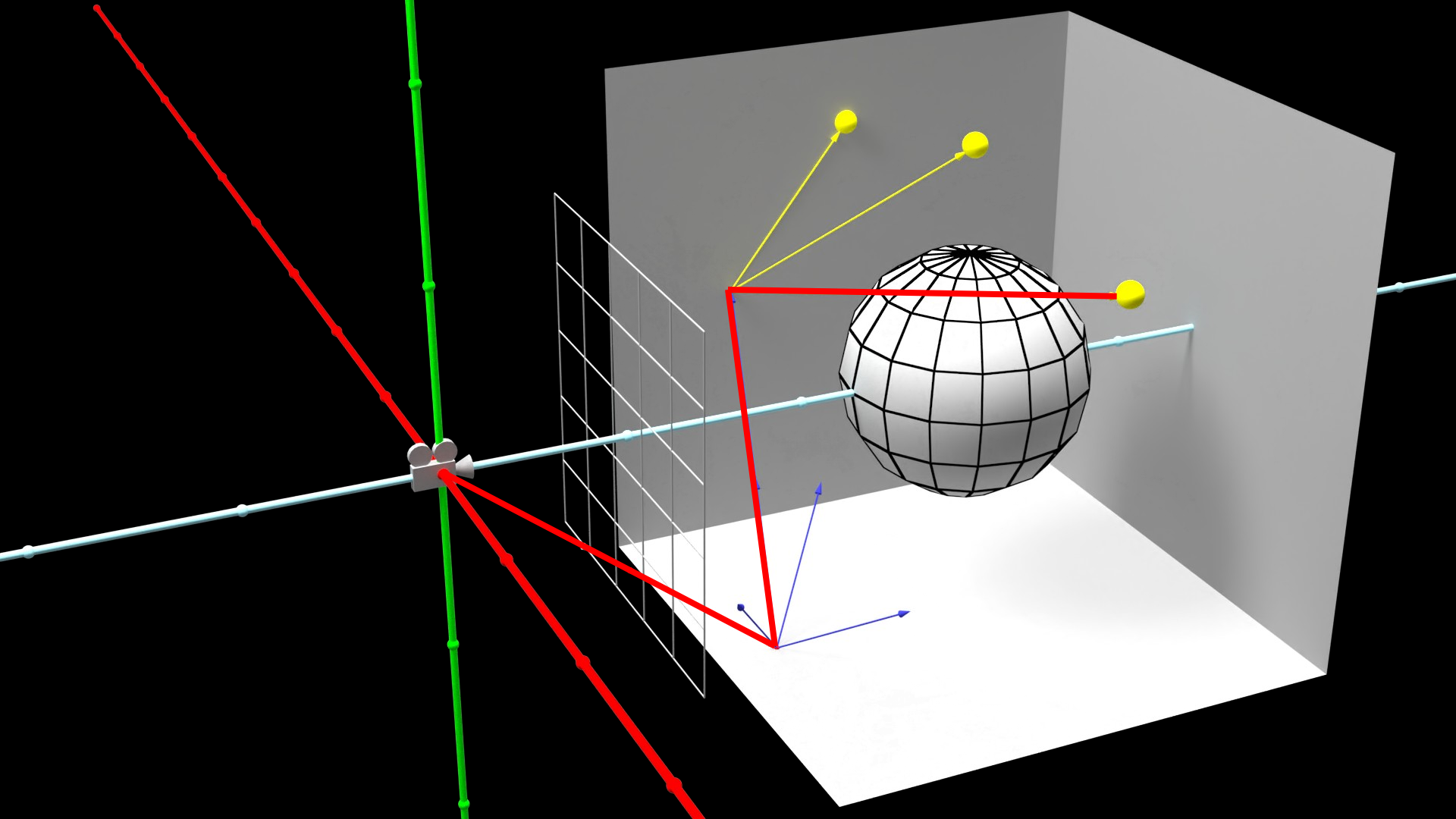


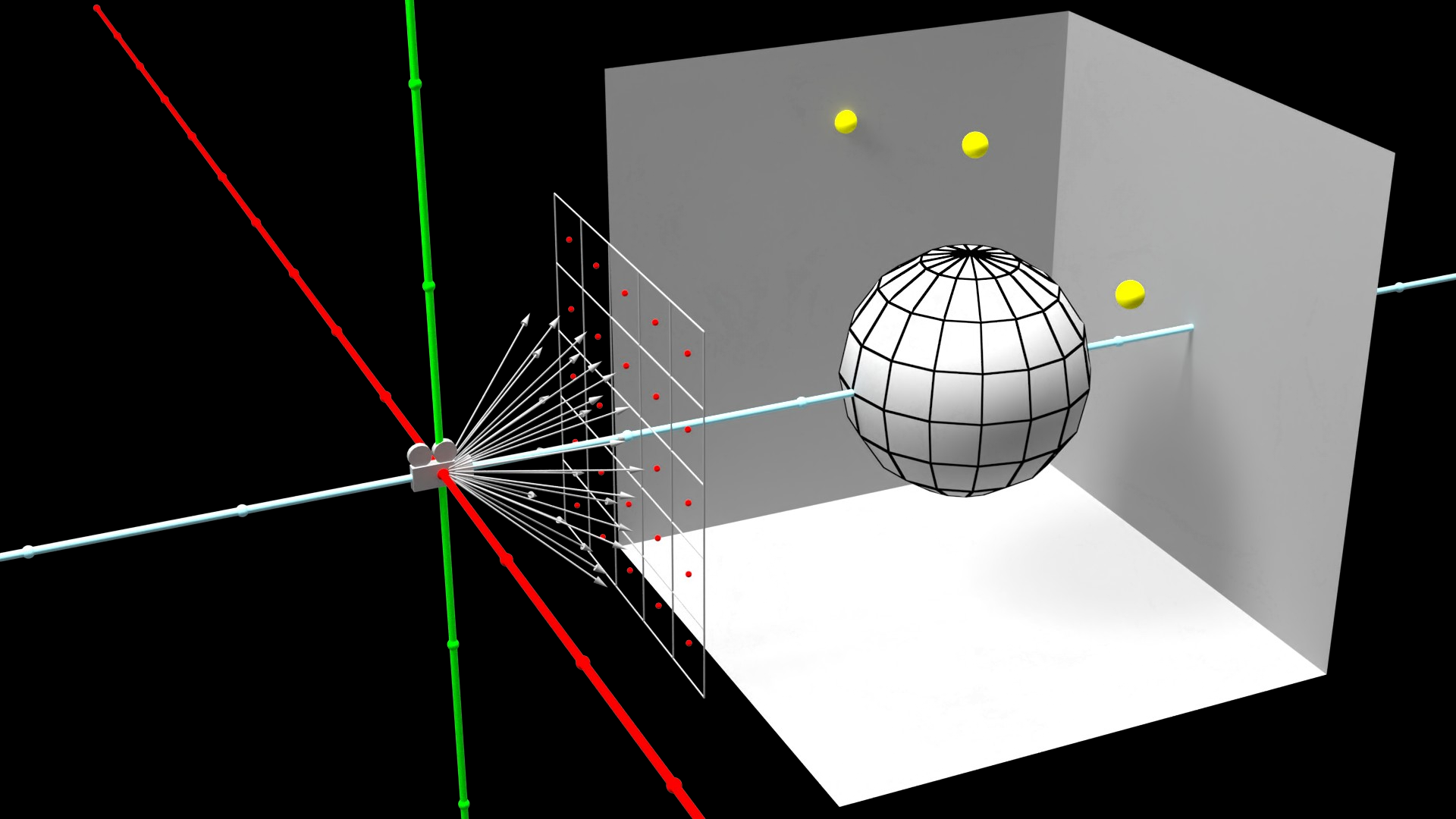


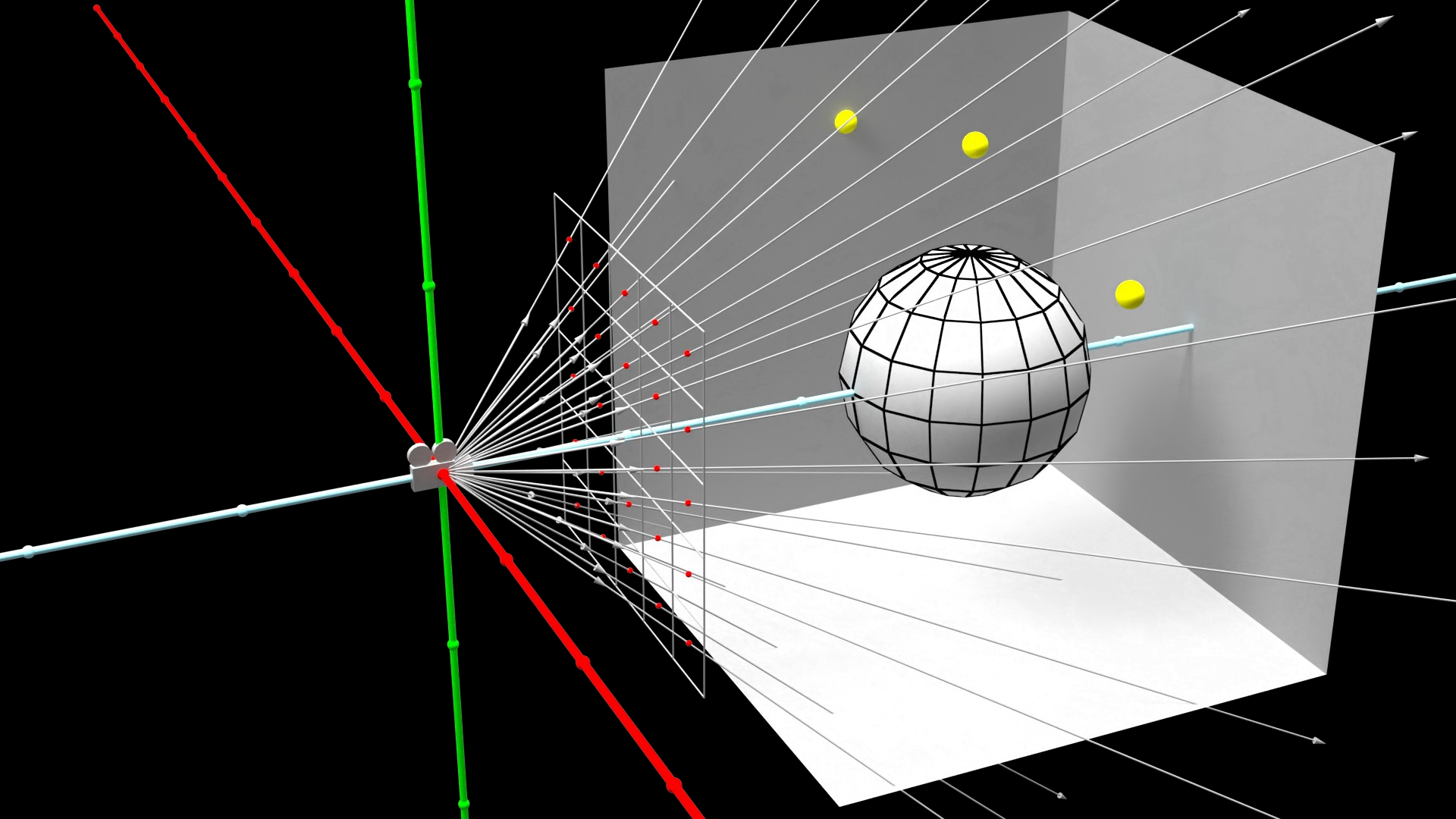






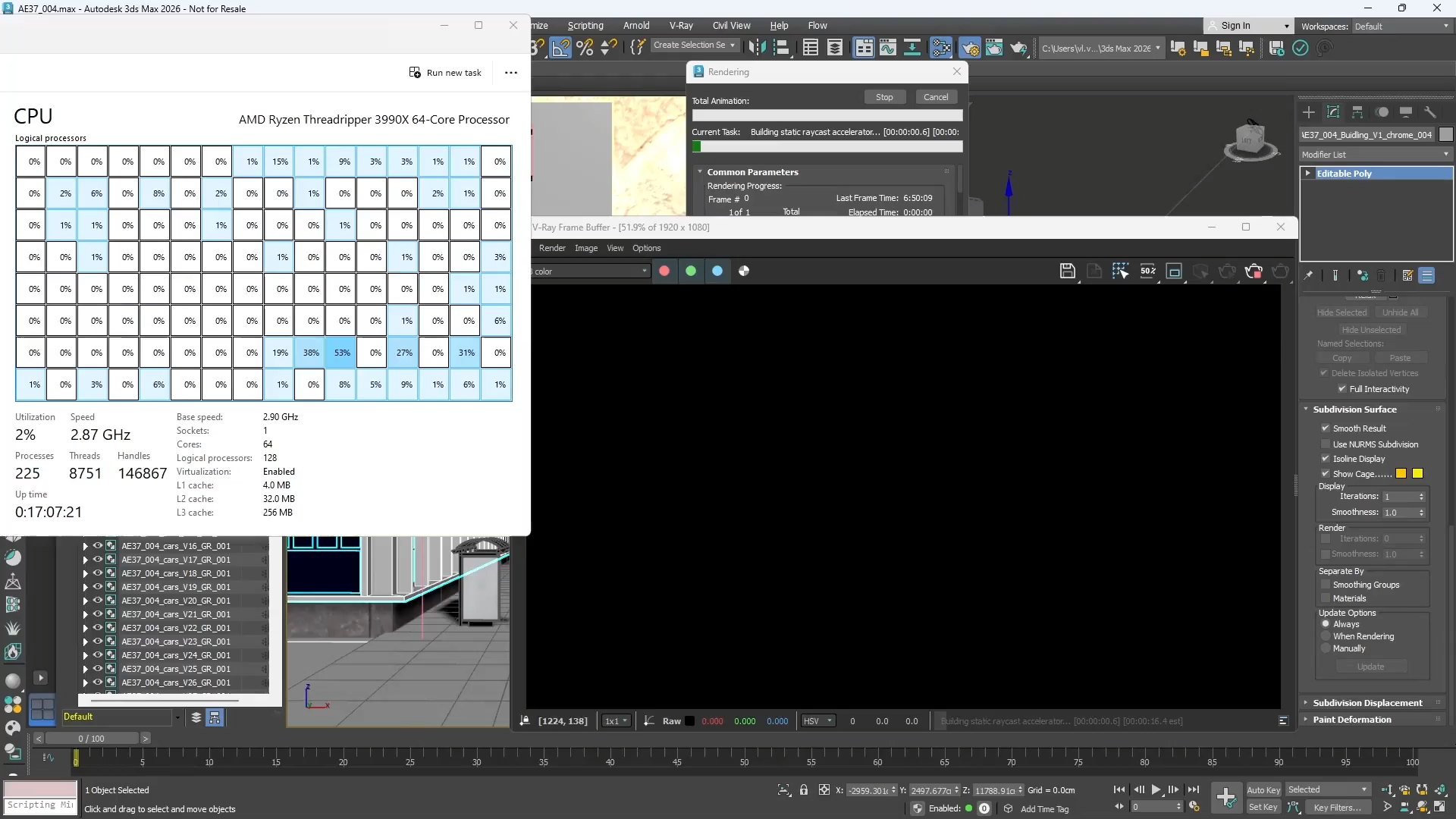






intel

intel


AE37_004.max - Autodesk 3ds Max 2026 - Not for Resale
Run new task
CPU
AMD Ryzen Threadripper 3990X 64-Core Processor
Logical processors
Utilization
2%
Speed
2.87 GHz
Processes
225
Threads
8751
Handles
146867
Up time
0:17:07:21
Base speed: 2.90 GHz
Sockets: 1
Cores: 64
Logical processors: 128
Virtualization: Enabled
L1 cache: 4.0 MB
L2 cache: 32.0 MB
L3 cache: 256 MB
Rendering
Total Animation:
Stop
Cancel
Current Task: Building static raycast accelerator... [00:00:00.6] [00:00:
Common Parameters
Rendering Progress:
Frame # 0
1 of 1
Total
Last Frame Time: 6:50:09
Elapsed Time: 0:00:00
V-Ray Frame Buffer - [51.9% of 1920 x 1080]
Render
Image
View
Options
Editable Poly
Subdivision Surface
Smooth Result
Use NURMS Subdivision
Isoline Display
Show Cage.....
Display
Iterations: 1
Smoothness: 1.0
Render
Iterations: 0
Smoothness: 1.0
Separate By
Smoothing Groups
Materials
Update Options
Always
When Rendering
Manually
Update
Subdivision Displacement
Paint Deformation
Hide Selected
Unhide All
Hide Unselected
Named Selections:
Copy
Paste
Delete Isolated Vertices
Full Interactivity
AE37_004_cars_V16_GR_001
AE37_004_cars_V17_GR_001
AE37_004_cars_V18_GR_001
AE37_004_cars_V19_GR_001
AE37_004_cars_V20_GR_001
AE37_004_cars_V21_GR_001
AE37_004_cars_V22_GR_001
AE37_004_cars_V23_GR_001
AE37_004_cars_V24_GR_001
AE37_004_cars_V25_GR_001
AE37_004_cars_V26_GR_001
Default
0 / 100
1 Object Selected
Click and drag to select and move objects
Add Time Tag
Auto Key
Set Key
Key Filters...

Optimizations

Multiple Importance Sampling

Optimizations

Multiple Importance Sampling

Russian roulette

Optimizations

Multiple Importance Sampling

Russian roulette

Optimizations

Path guiding

Acceleration data structures

Multiple Importance Sampling

Russian roulette

Optimizations

Path guiding

Acceleration data structures

Multiple Importance Sampling

Russian roulette

Optimizations

...

Path guiding

Hardware accelerations

Shadow queues

Acceleration data structures

Multiple Importance Sampling

Russian roulette

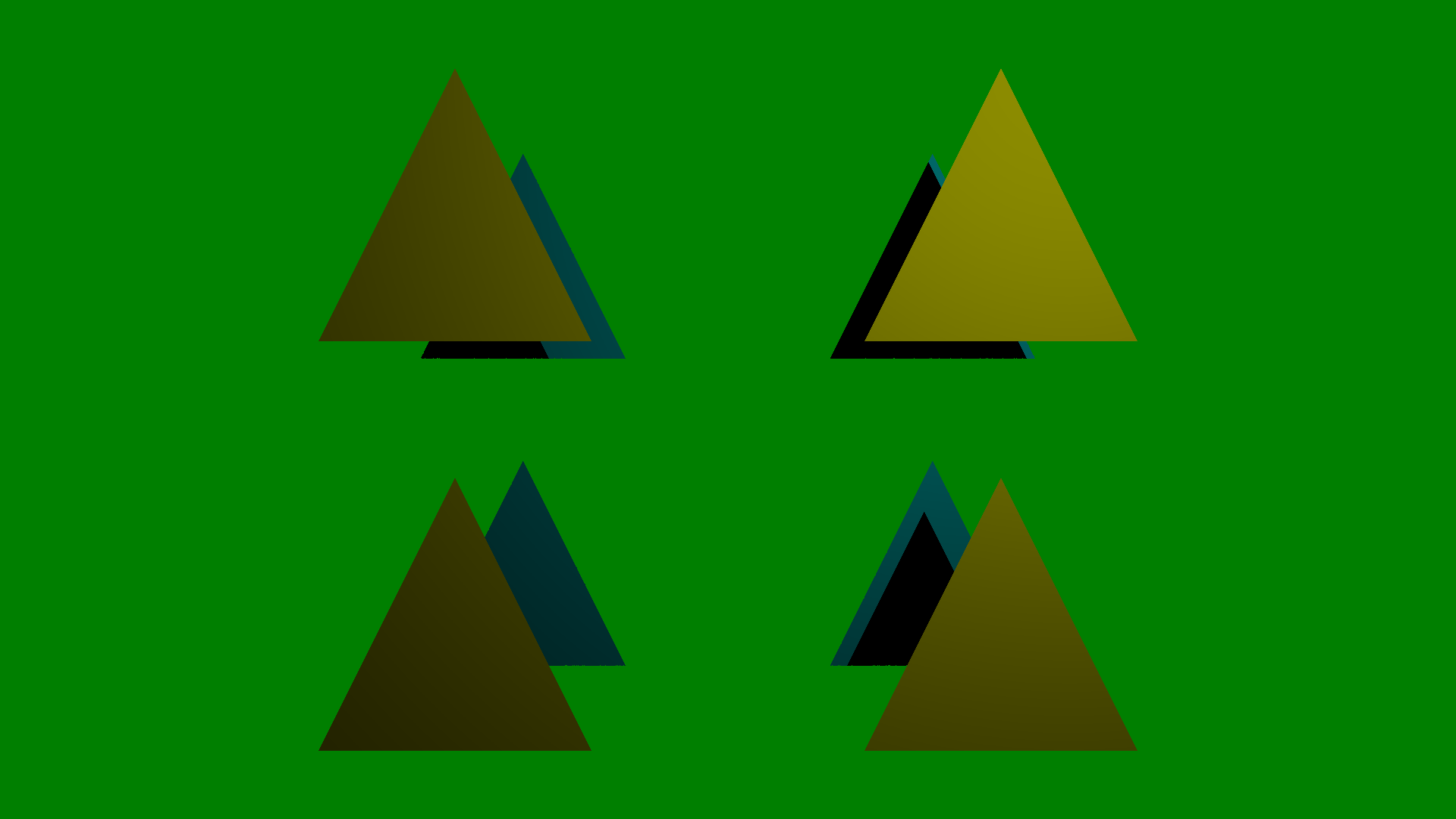
Optimizations

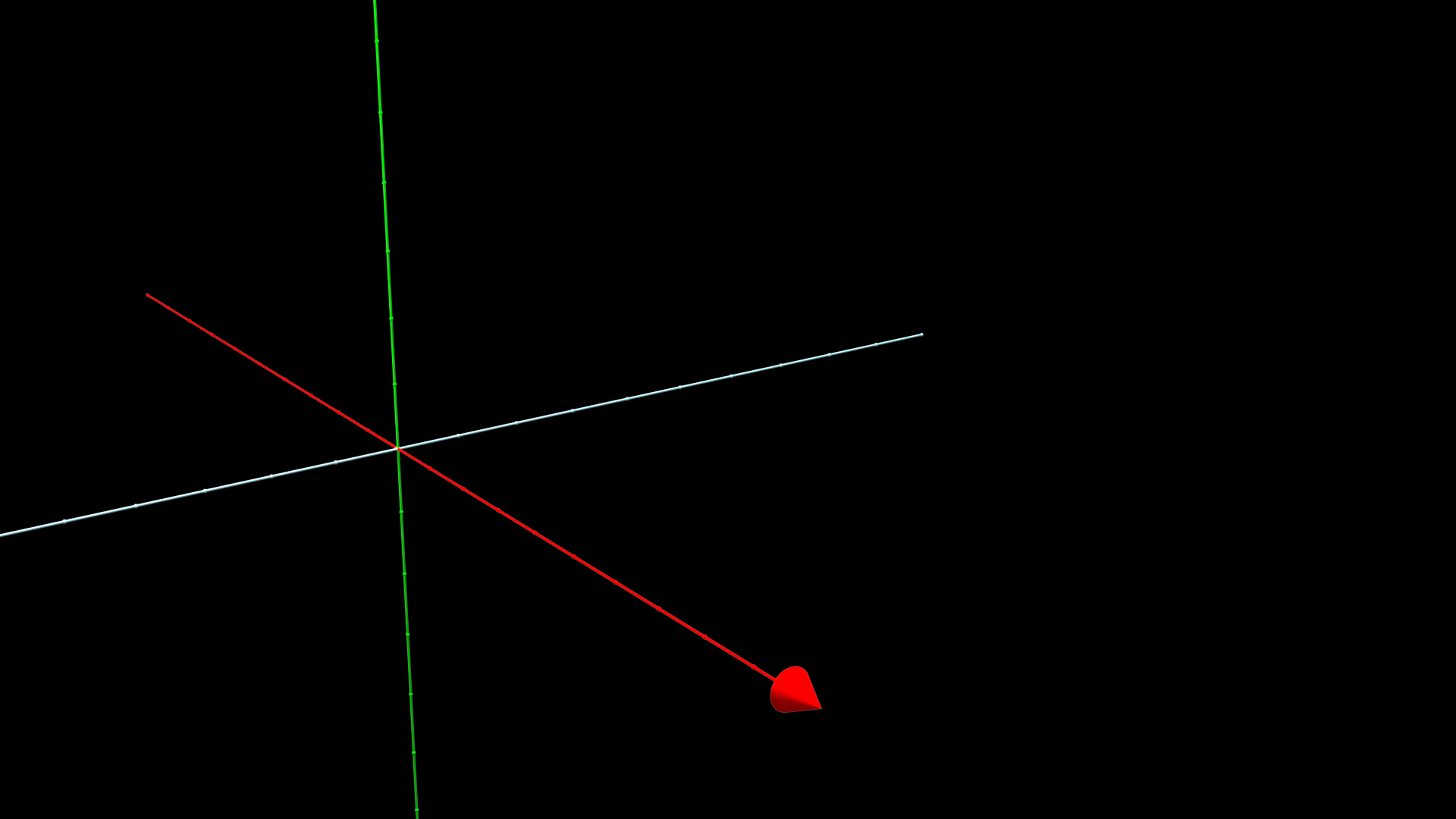
...

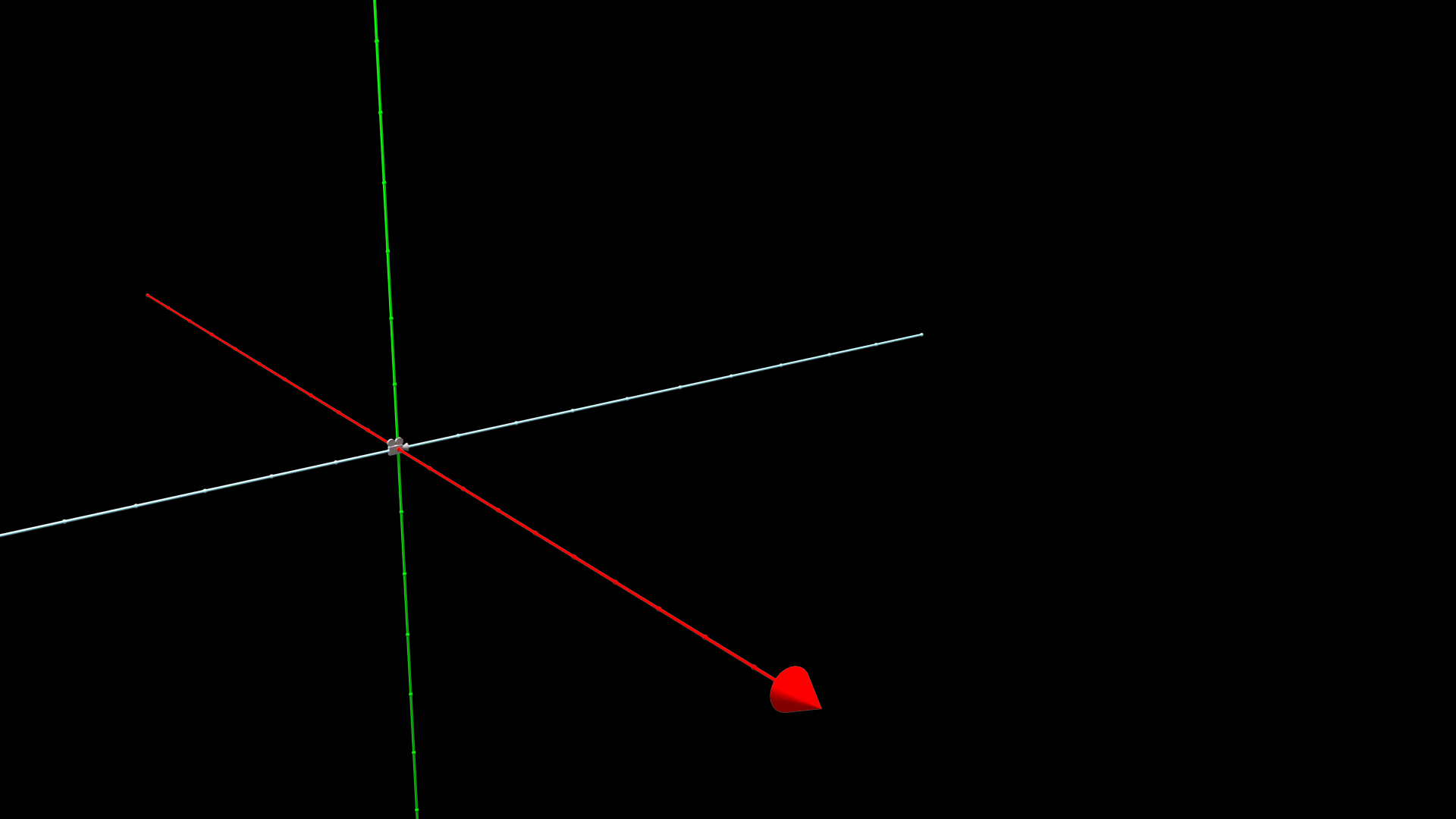
Path guiding

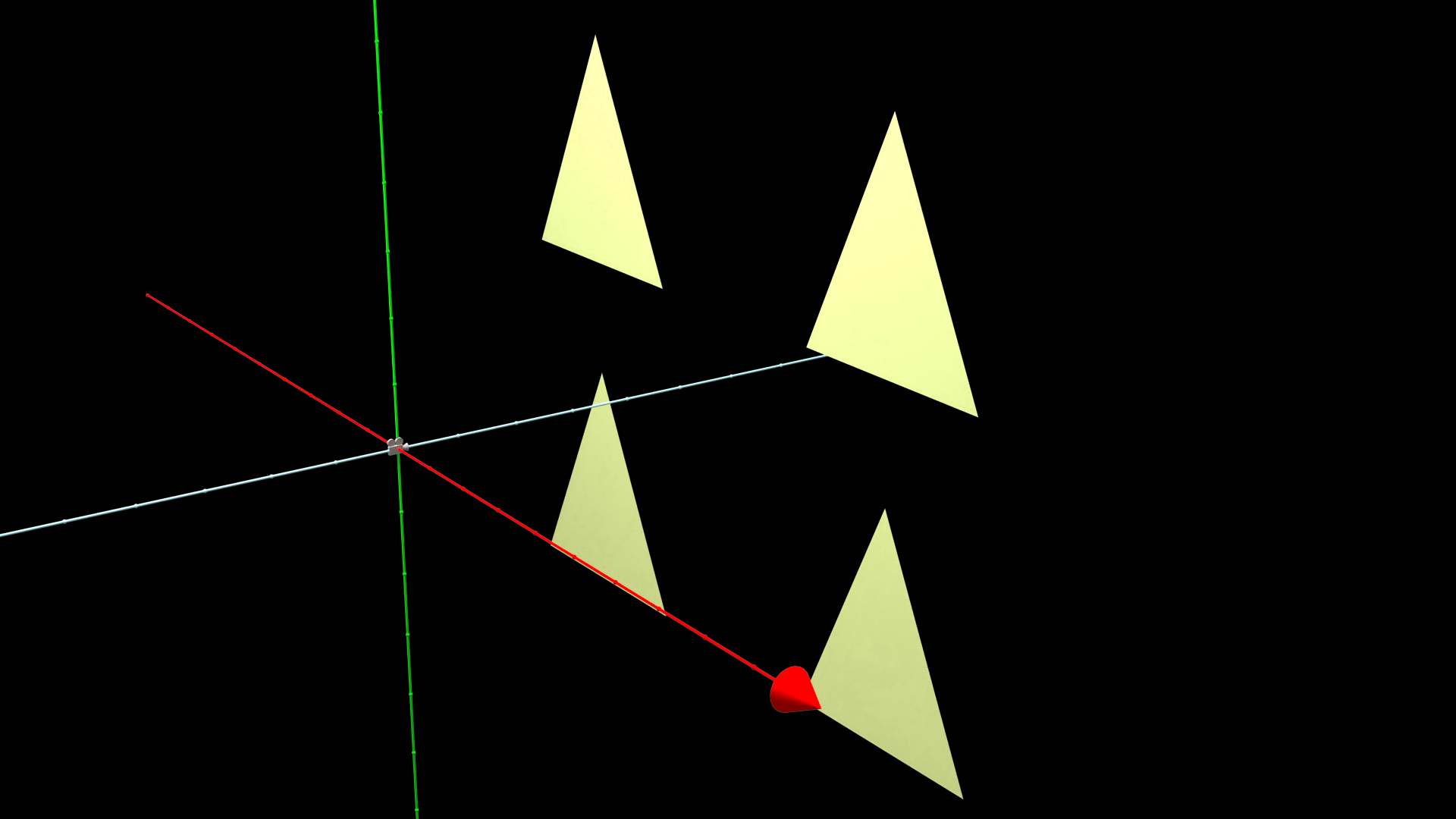
Hardware accelerations

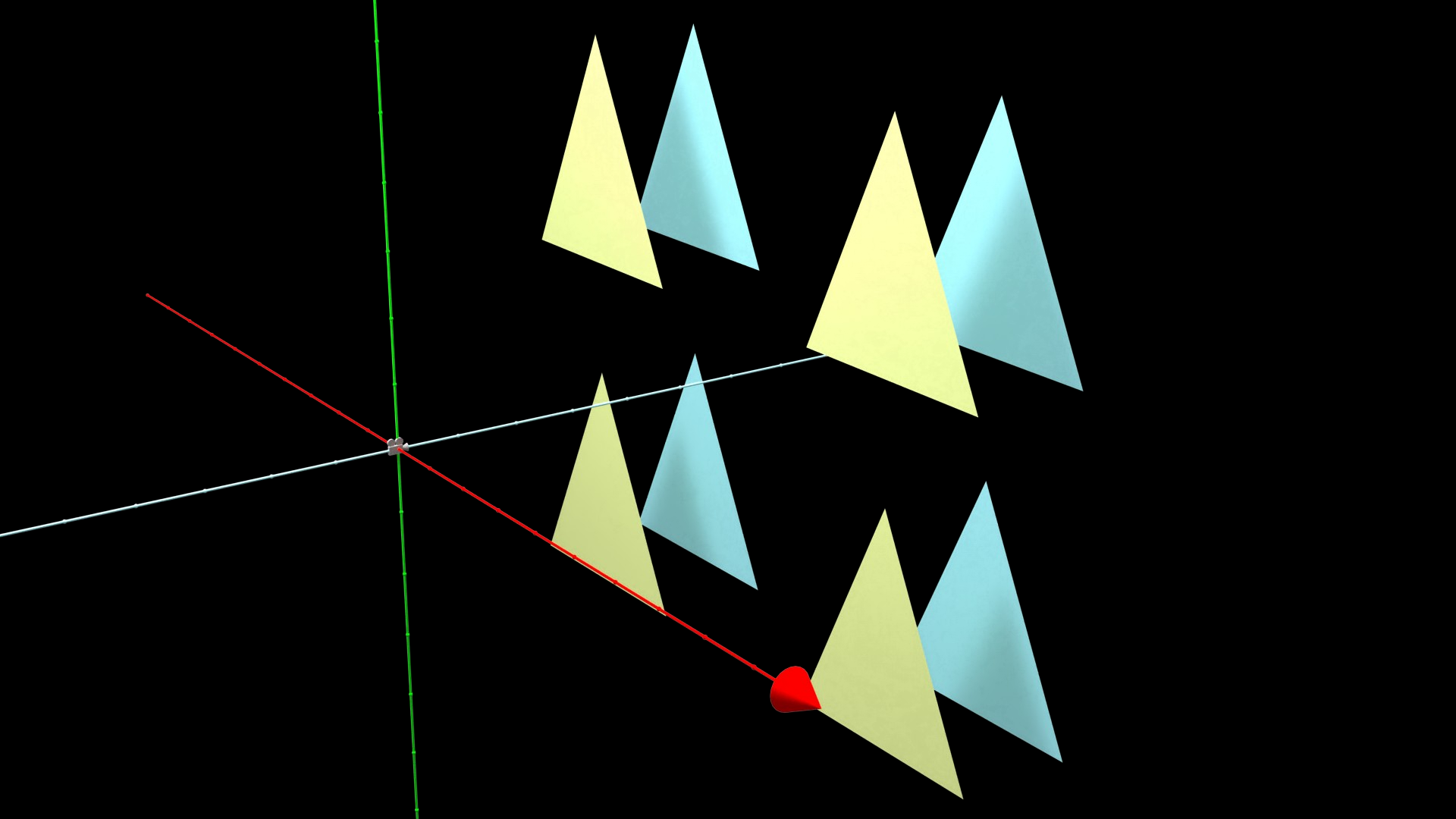
Shadow queues

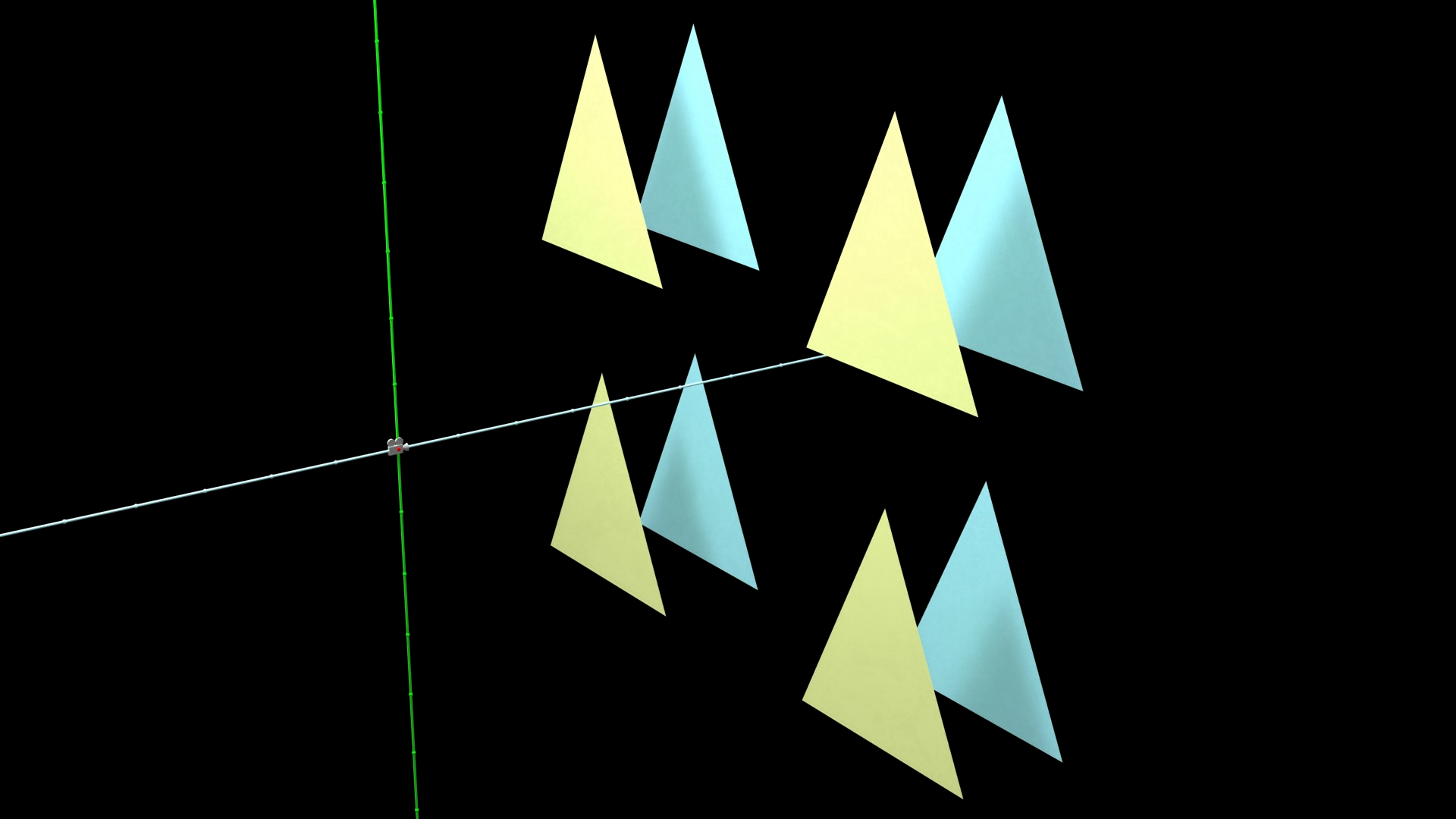


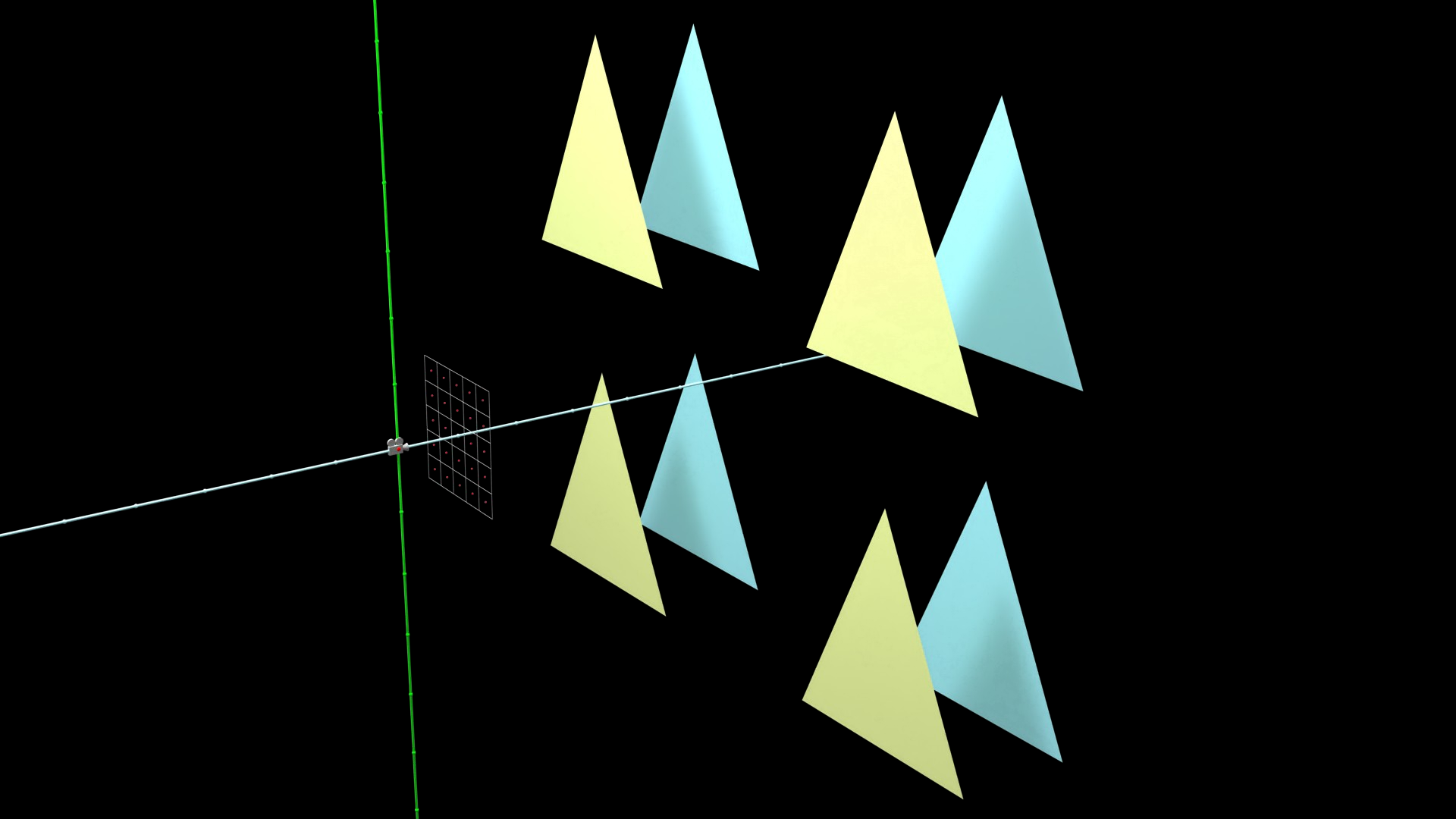


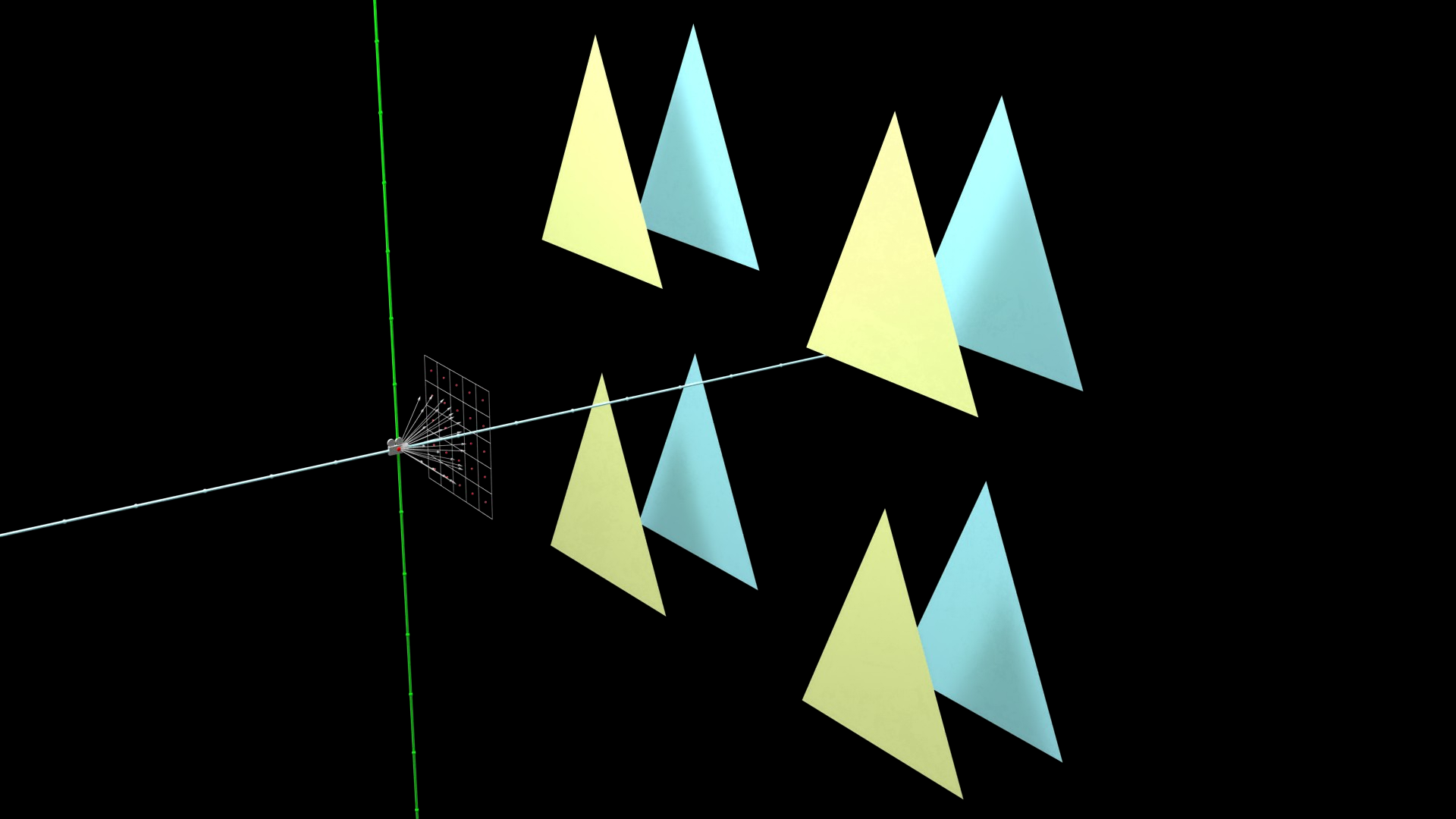


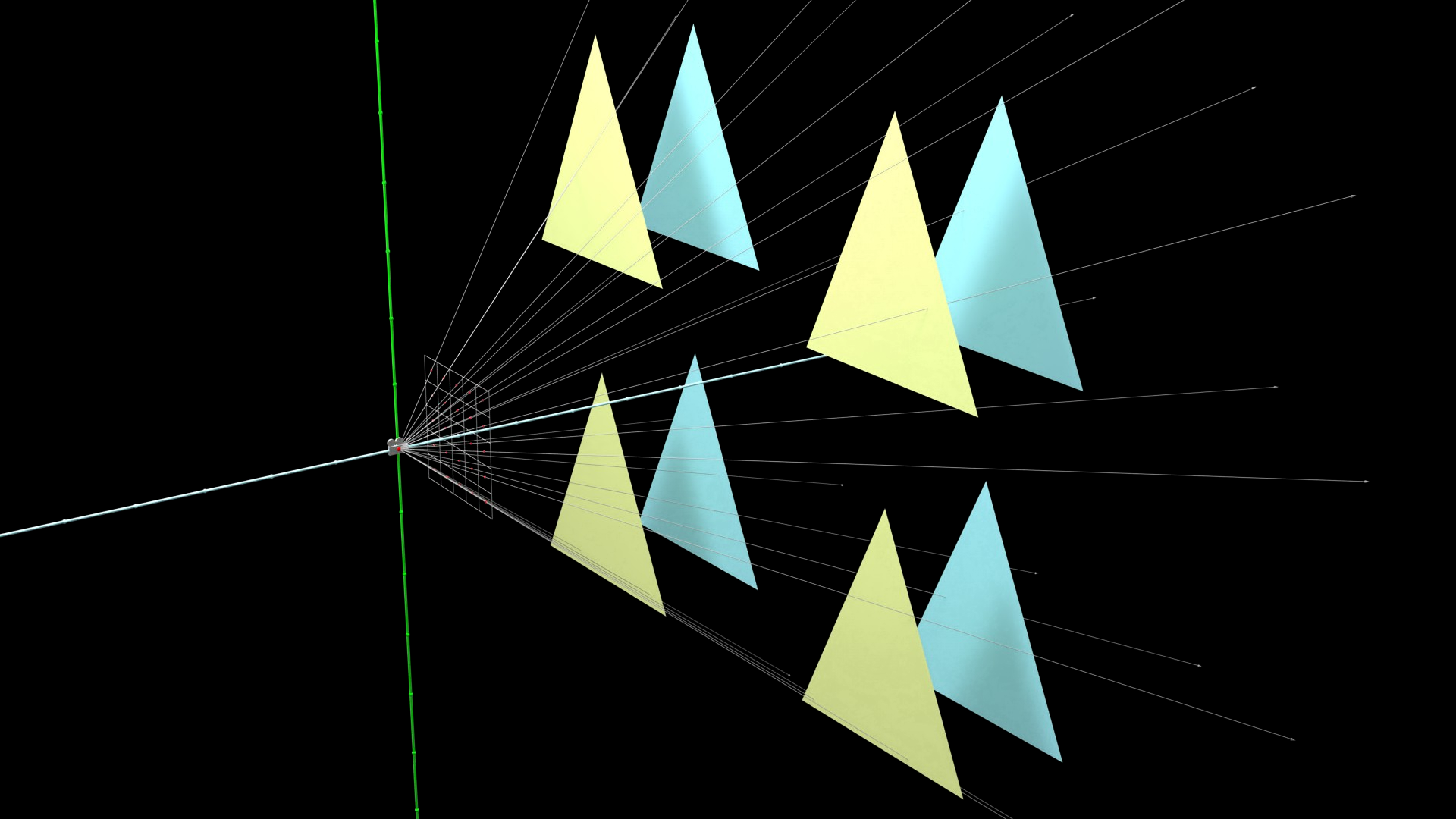


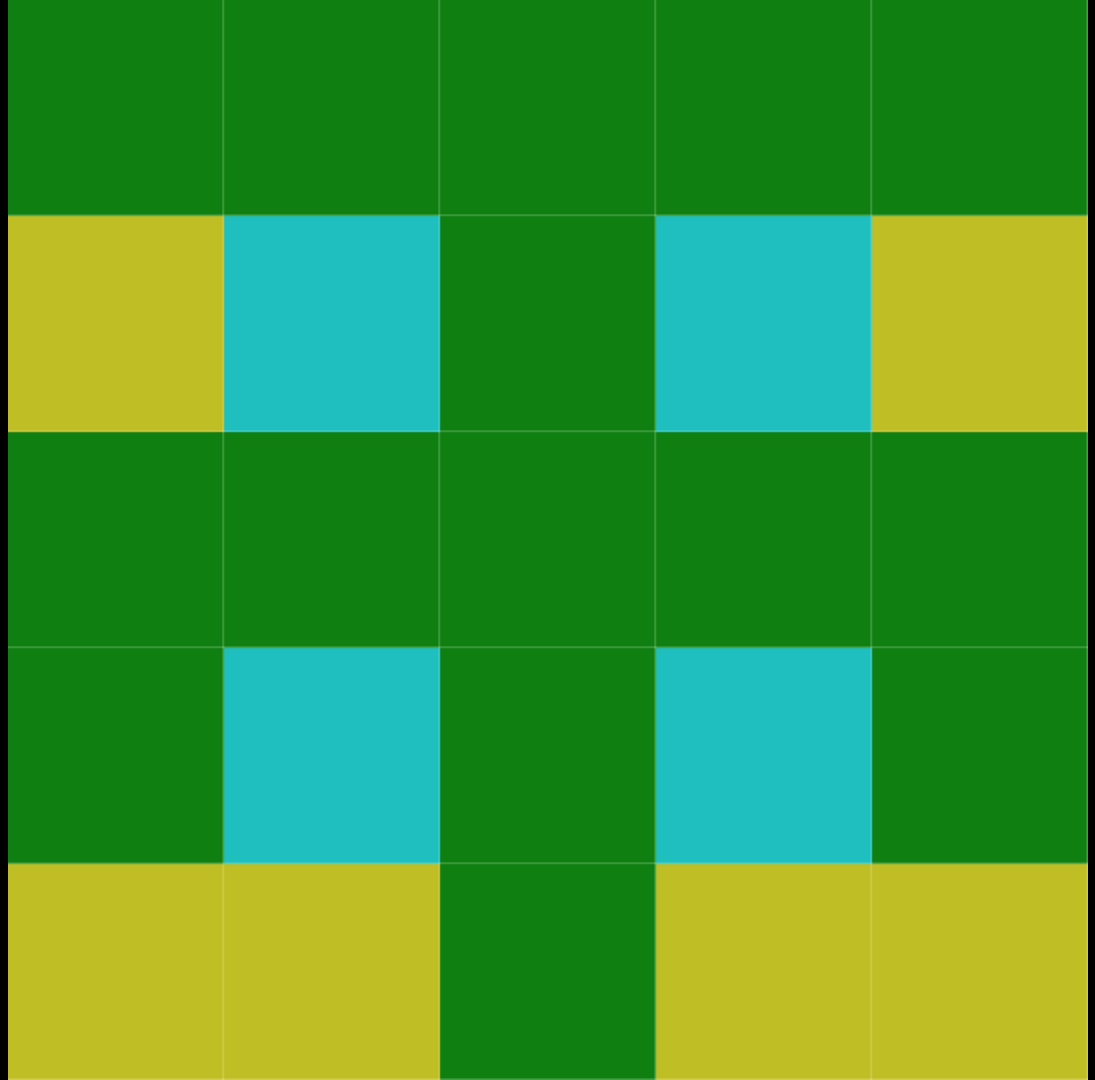






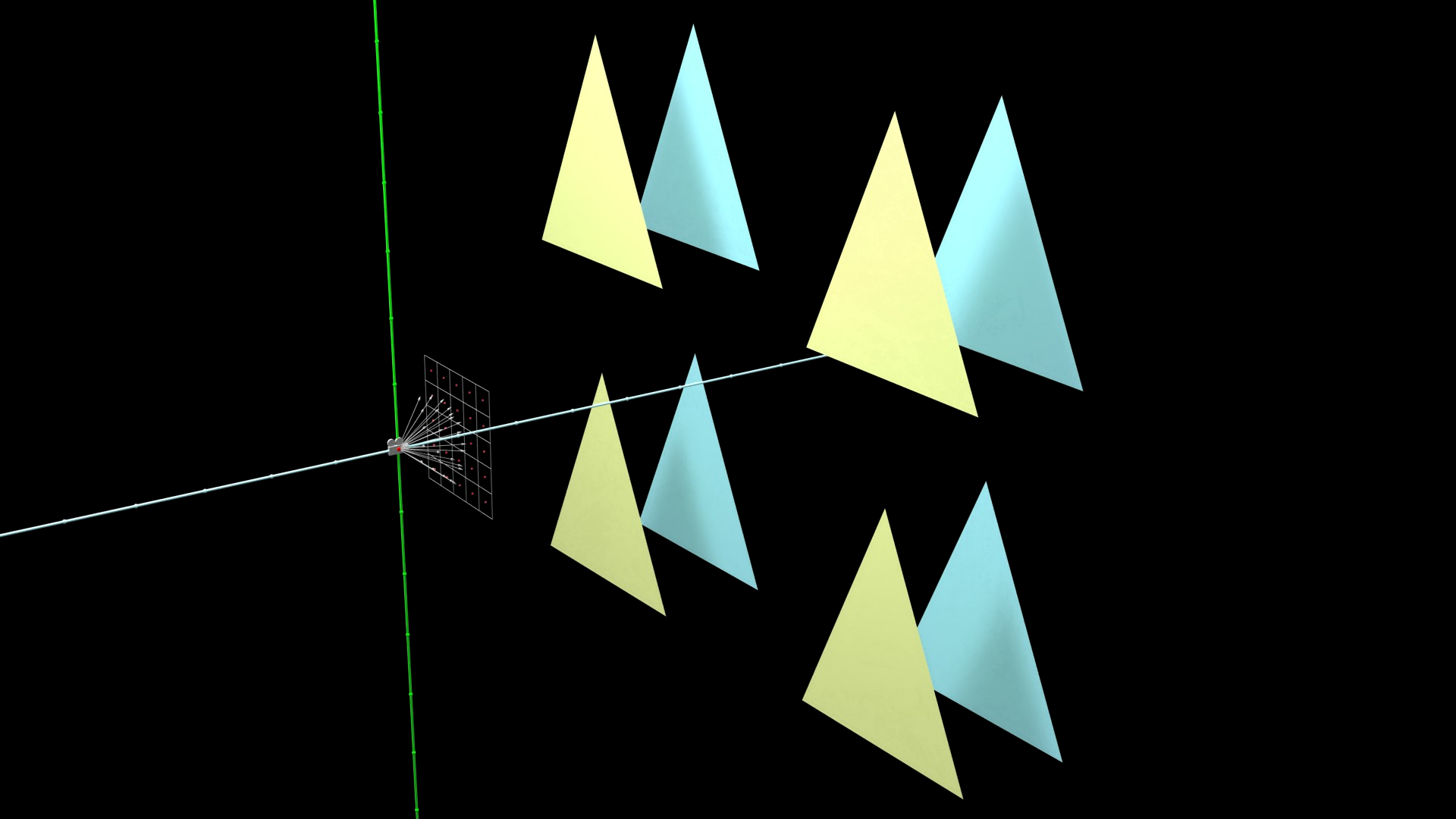


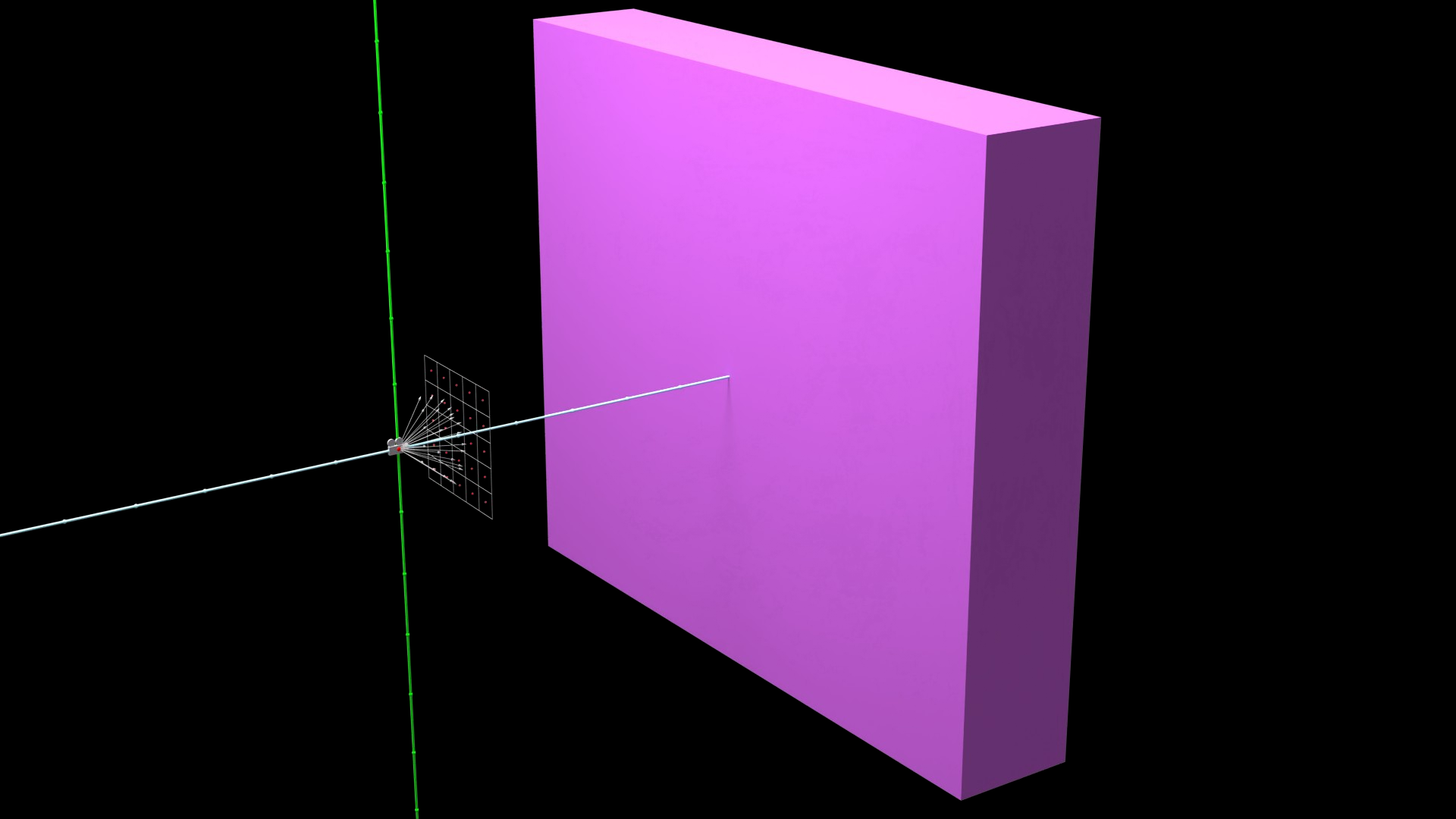


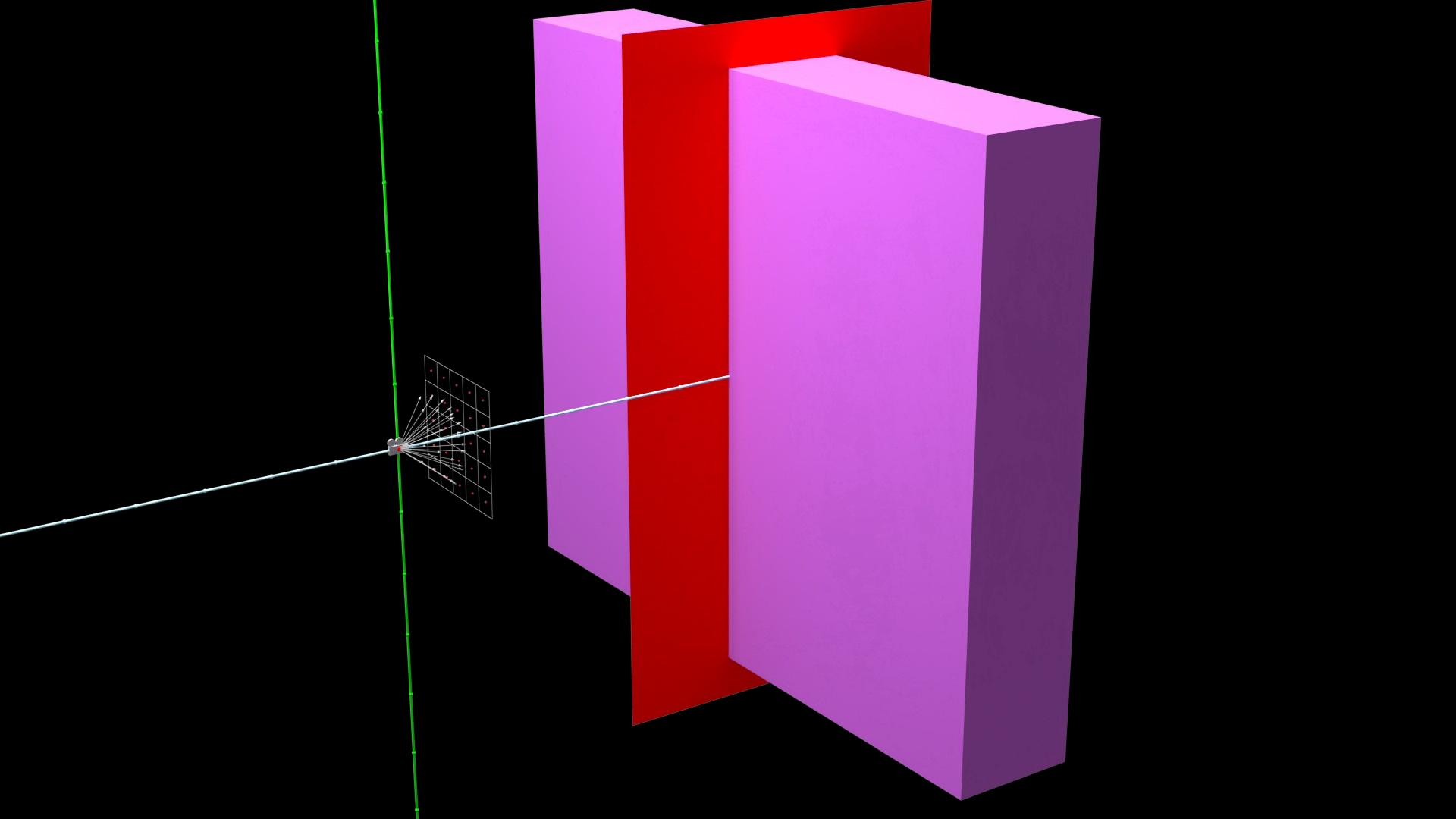


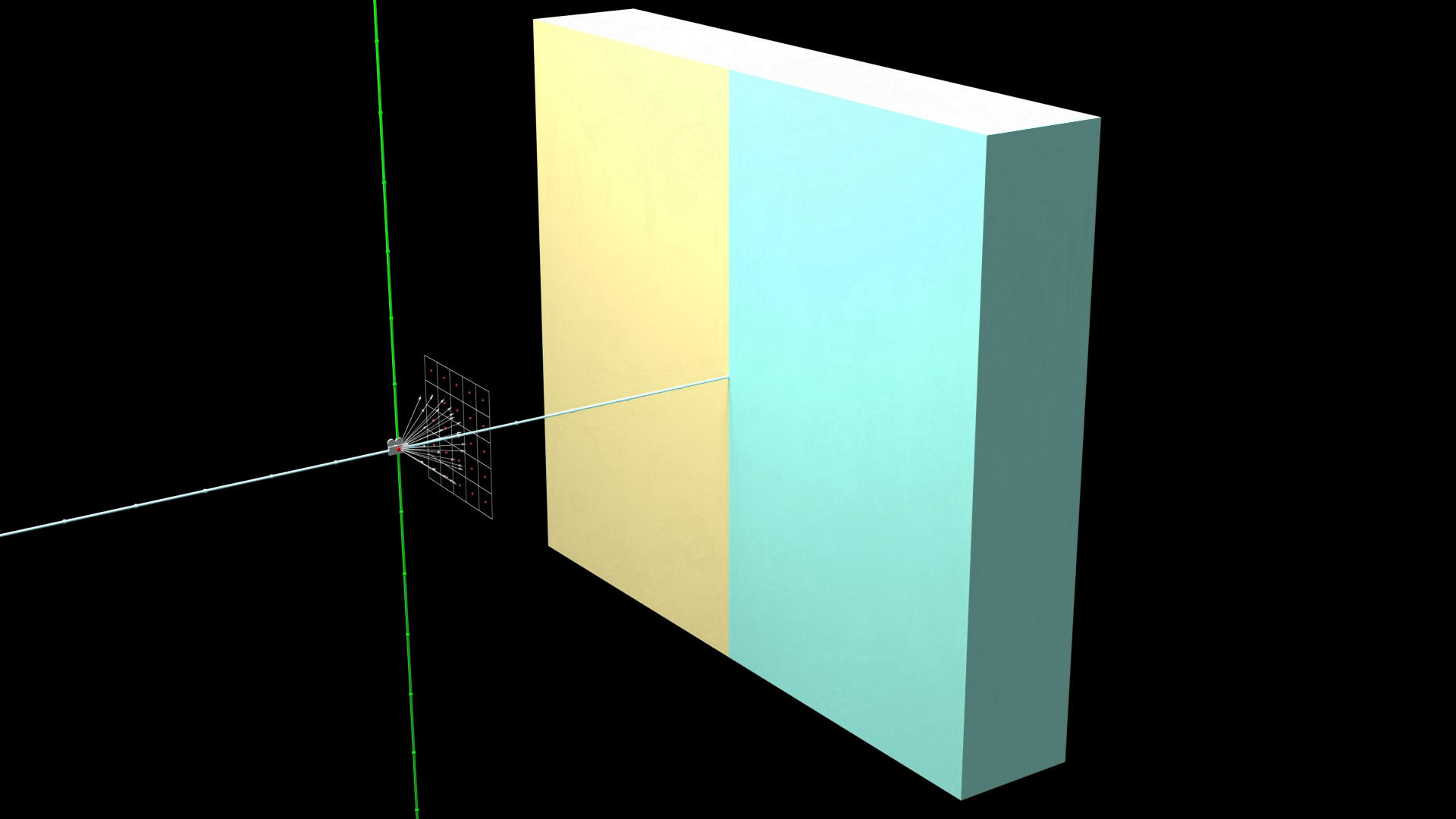
8 triangles checks	**8** triangles checks	**8** triangles checks	**8** triangles checks	**8** triangles checks
16 triangles checks	**16** triangles checks	**8** triangles checks	**16** triangles checks	**16** triangles checks
8 triangles checks	**8** triangles checks	**8** triangles checks	**8** triangles checks	**8** triangles checks
8 triangles checks	**16** triangles checks	**8** triangles checks	**16** triangles checks	**8** triangles checks
16 triangles checks	**16** triangles checks	**8** triangles checks	**16** triangles checks	**16** triangles checks

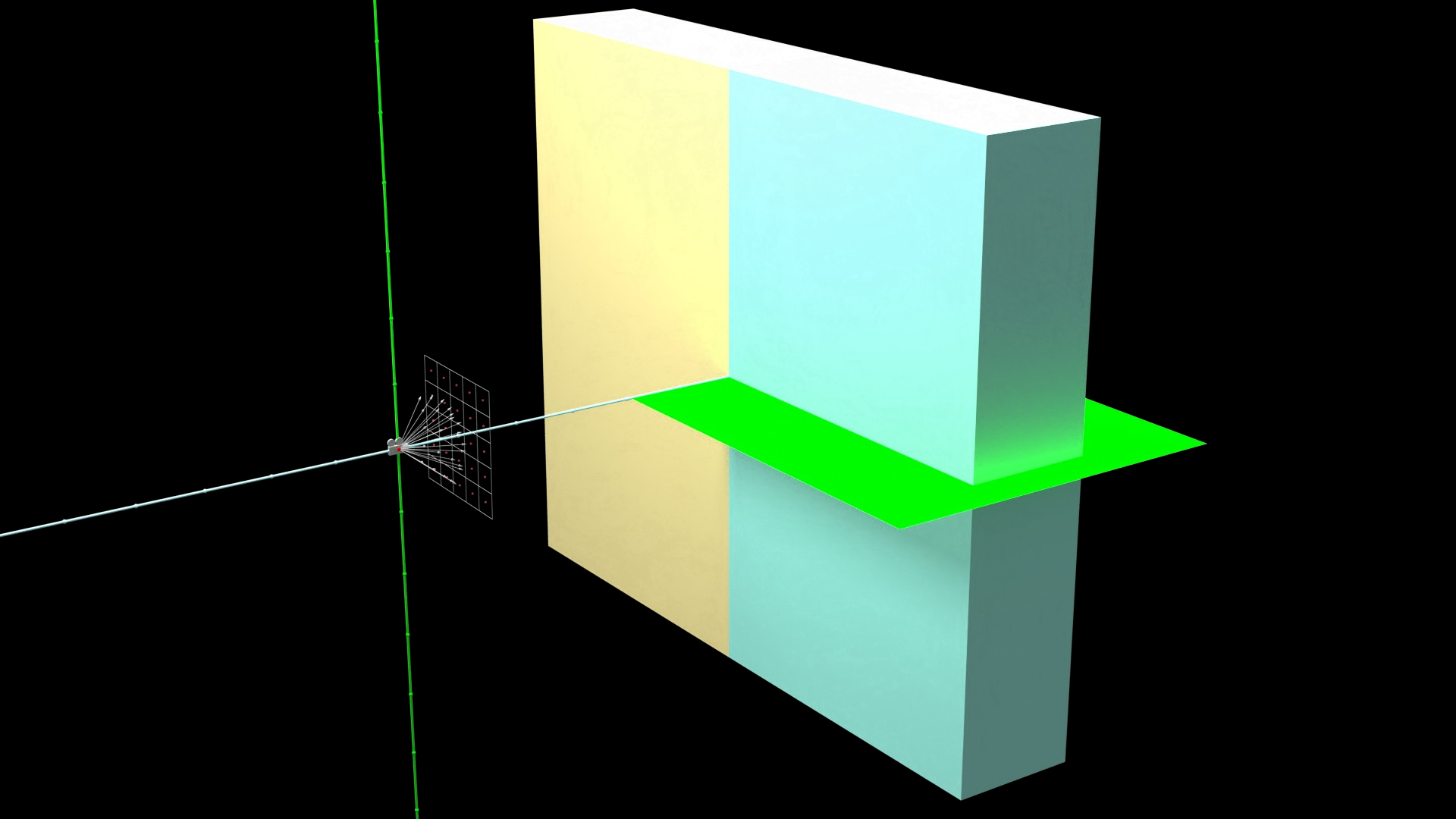
Acceleration Structure Build

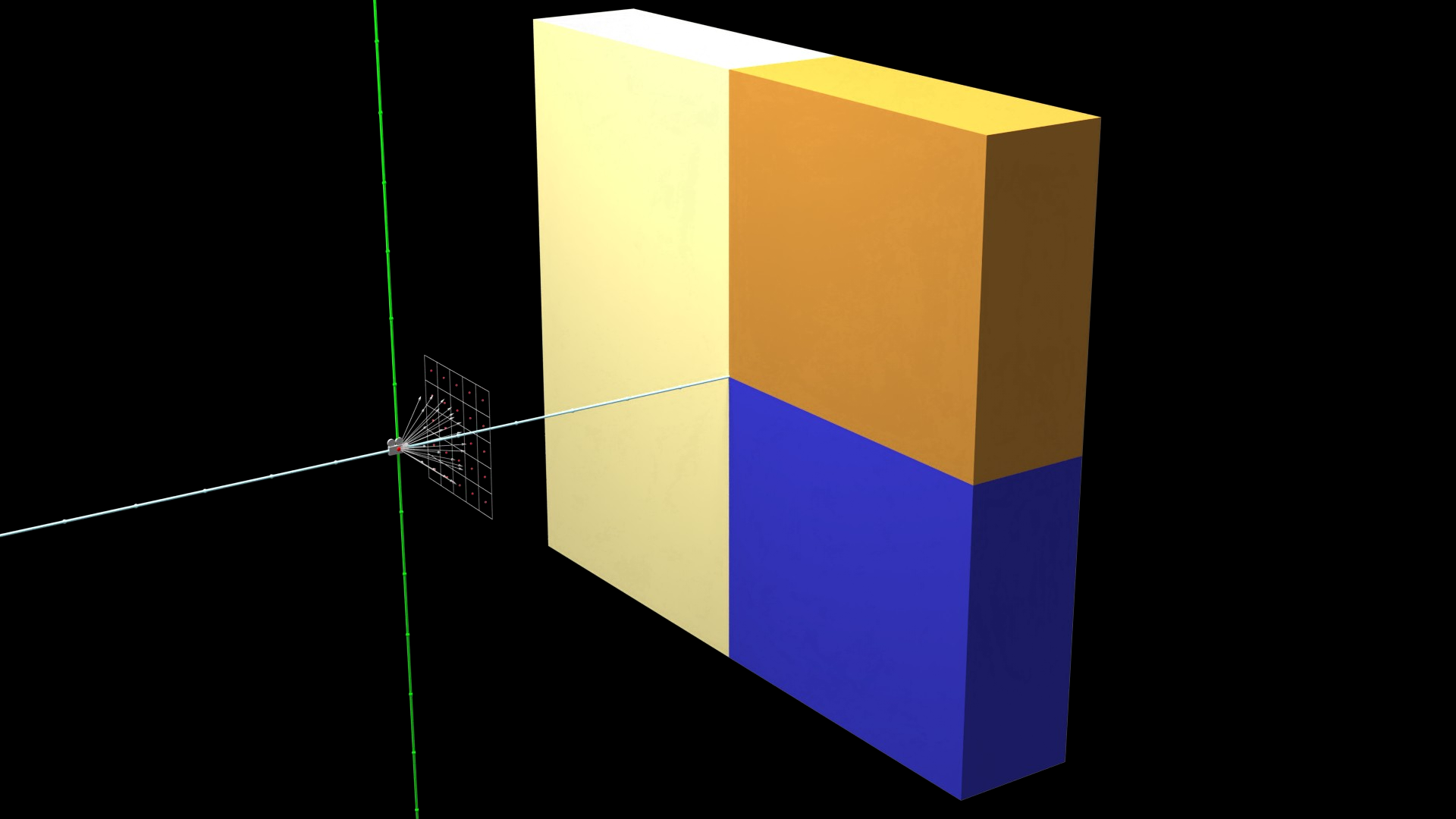


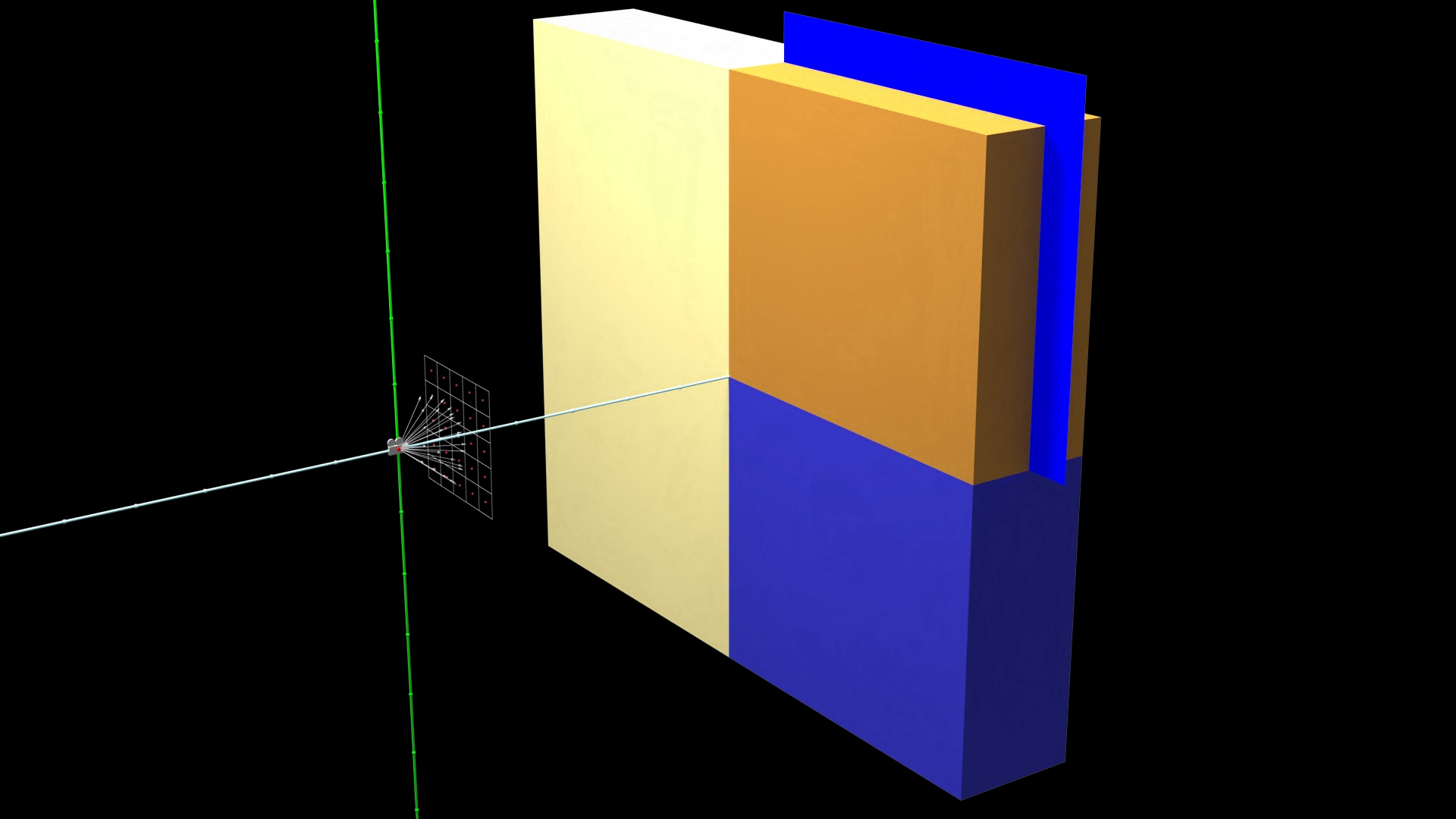


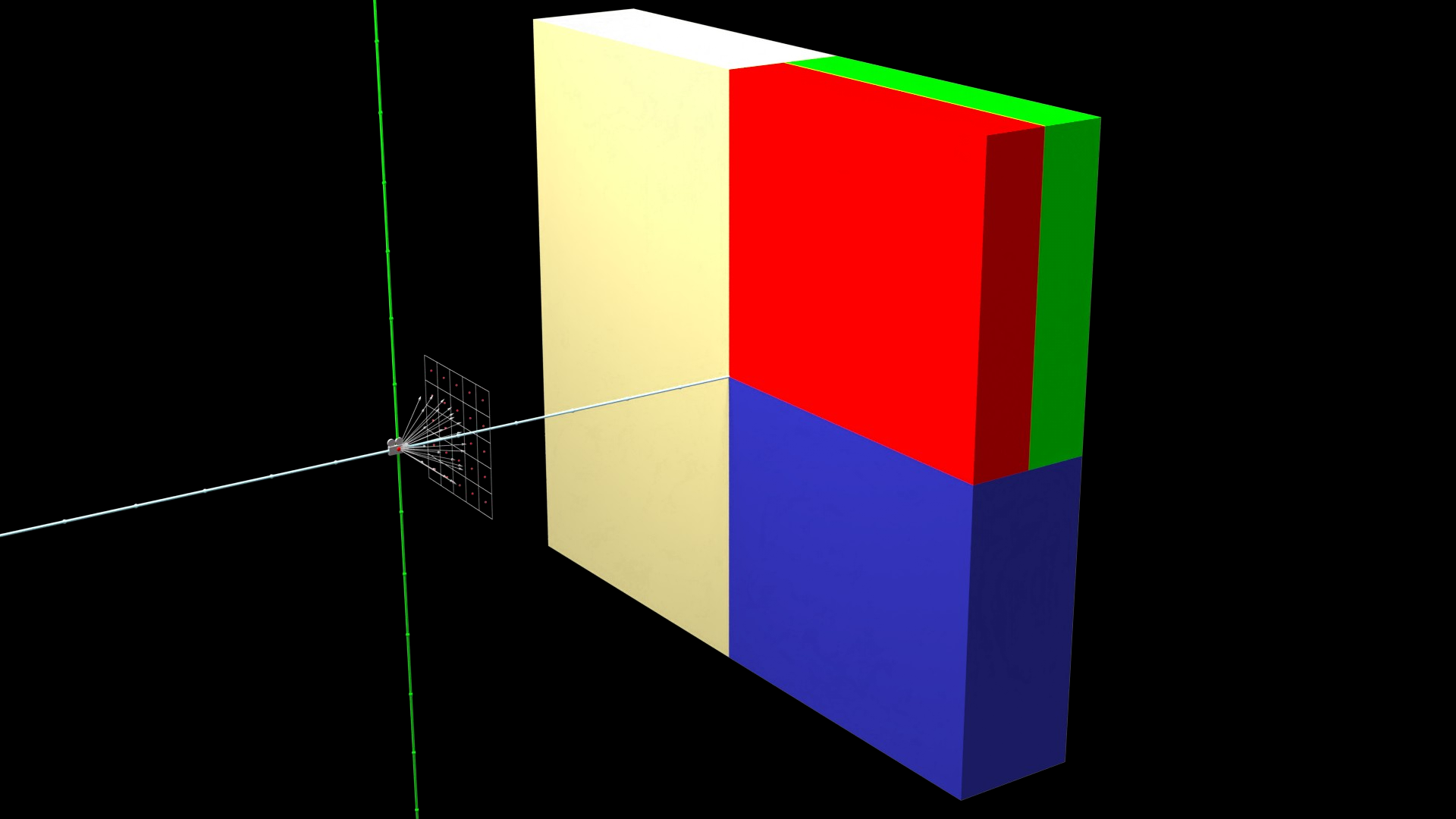


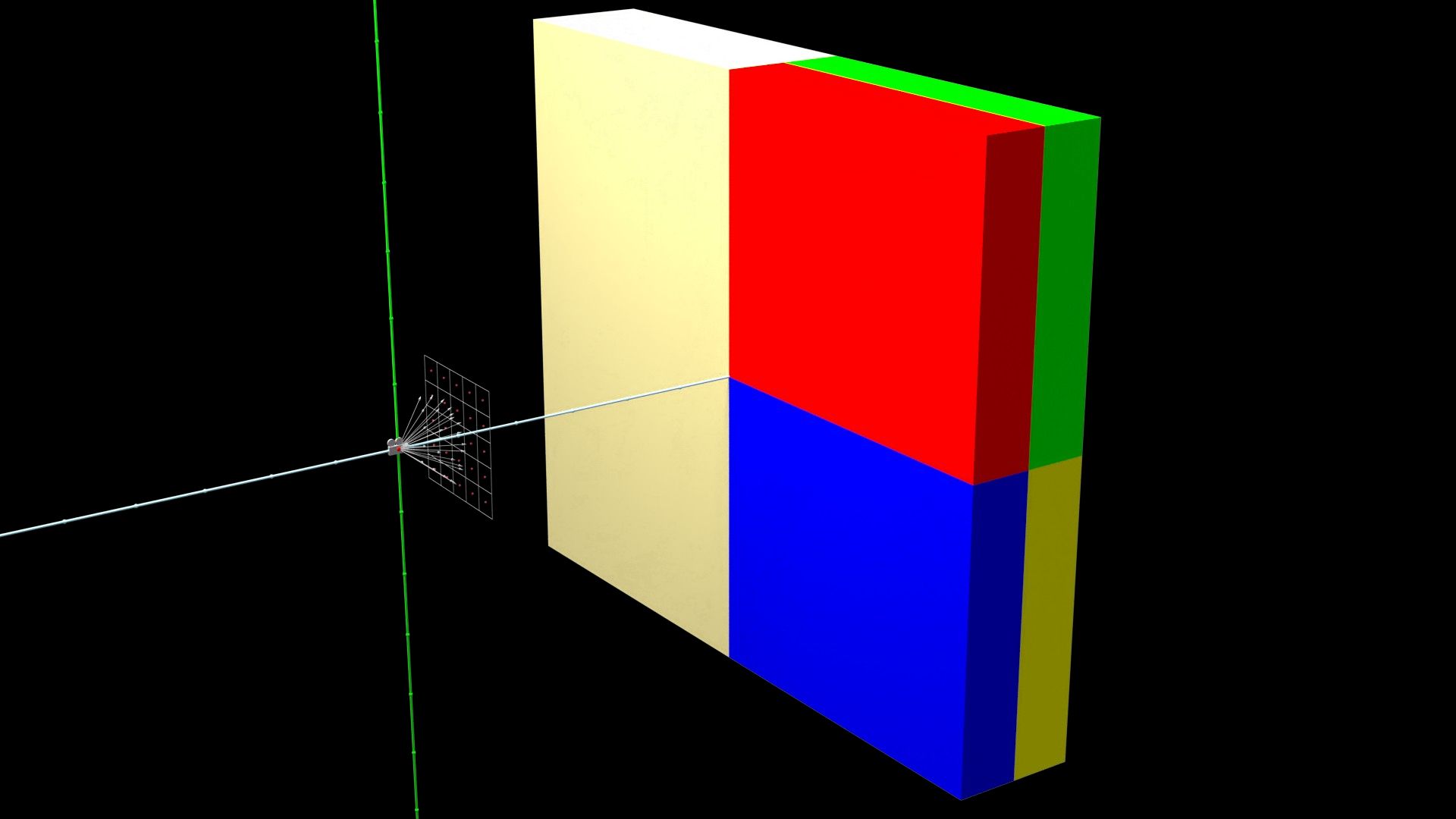


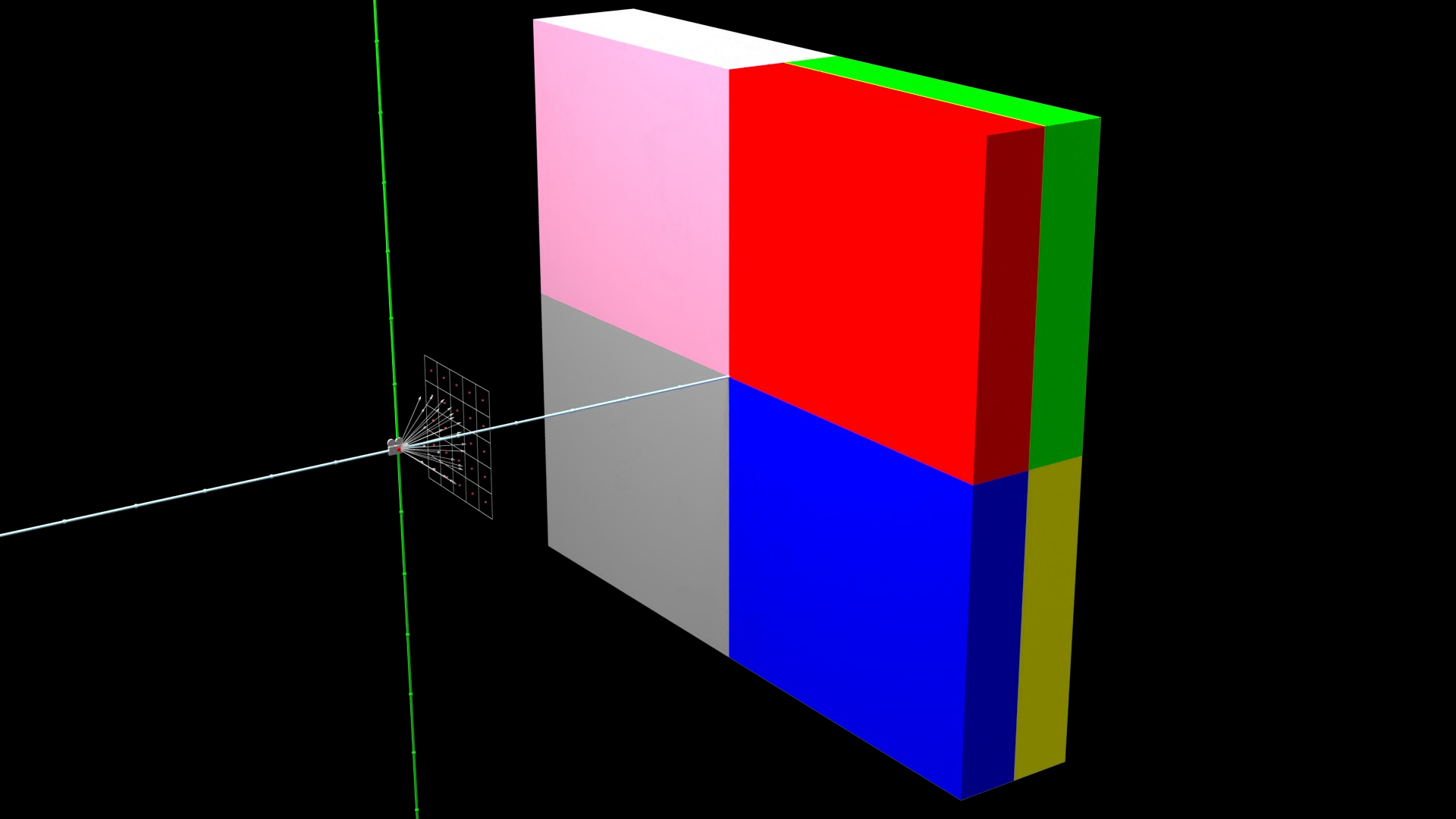


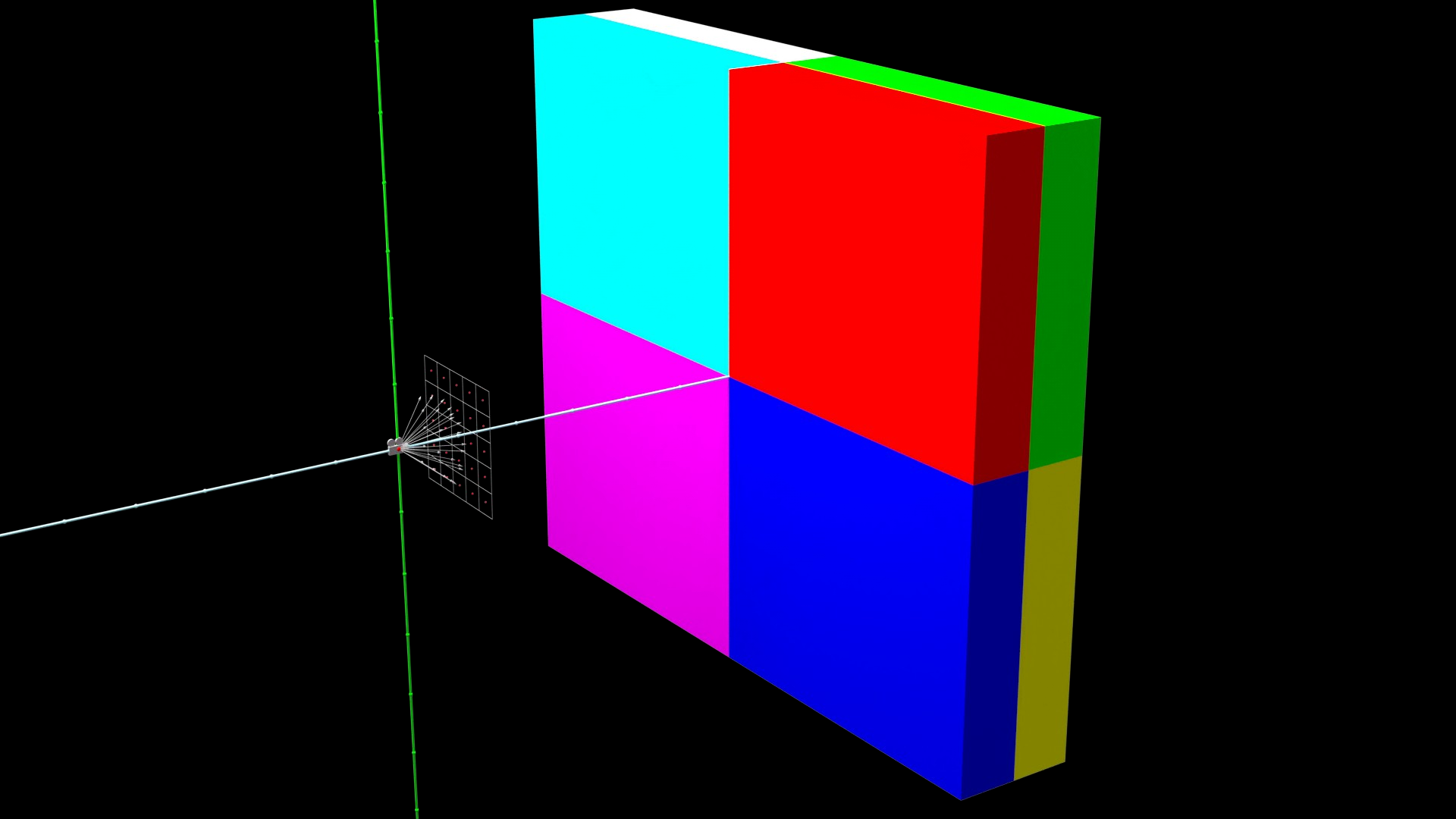




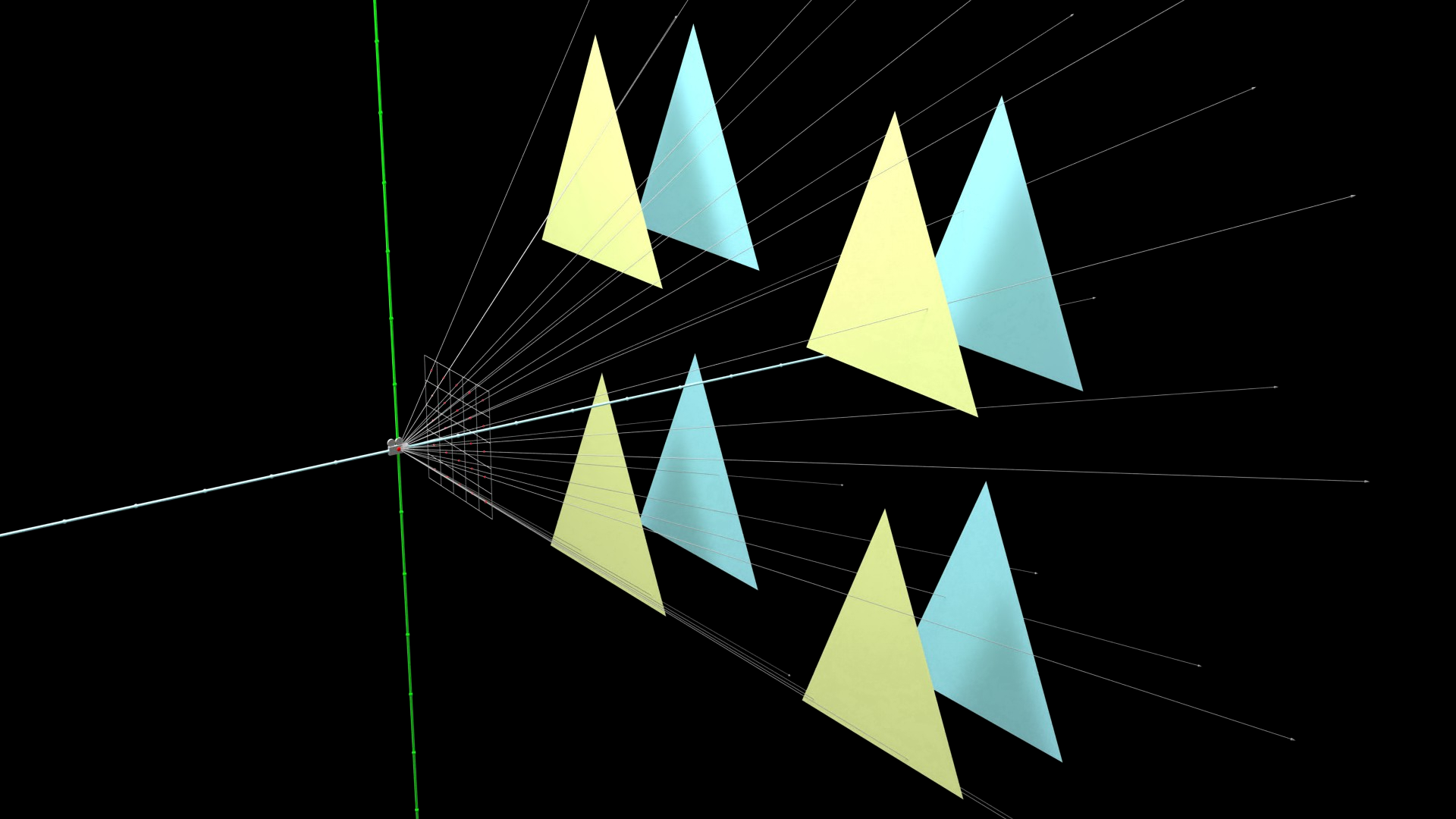


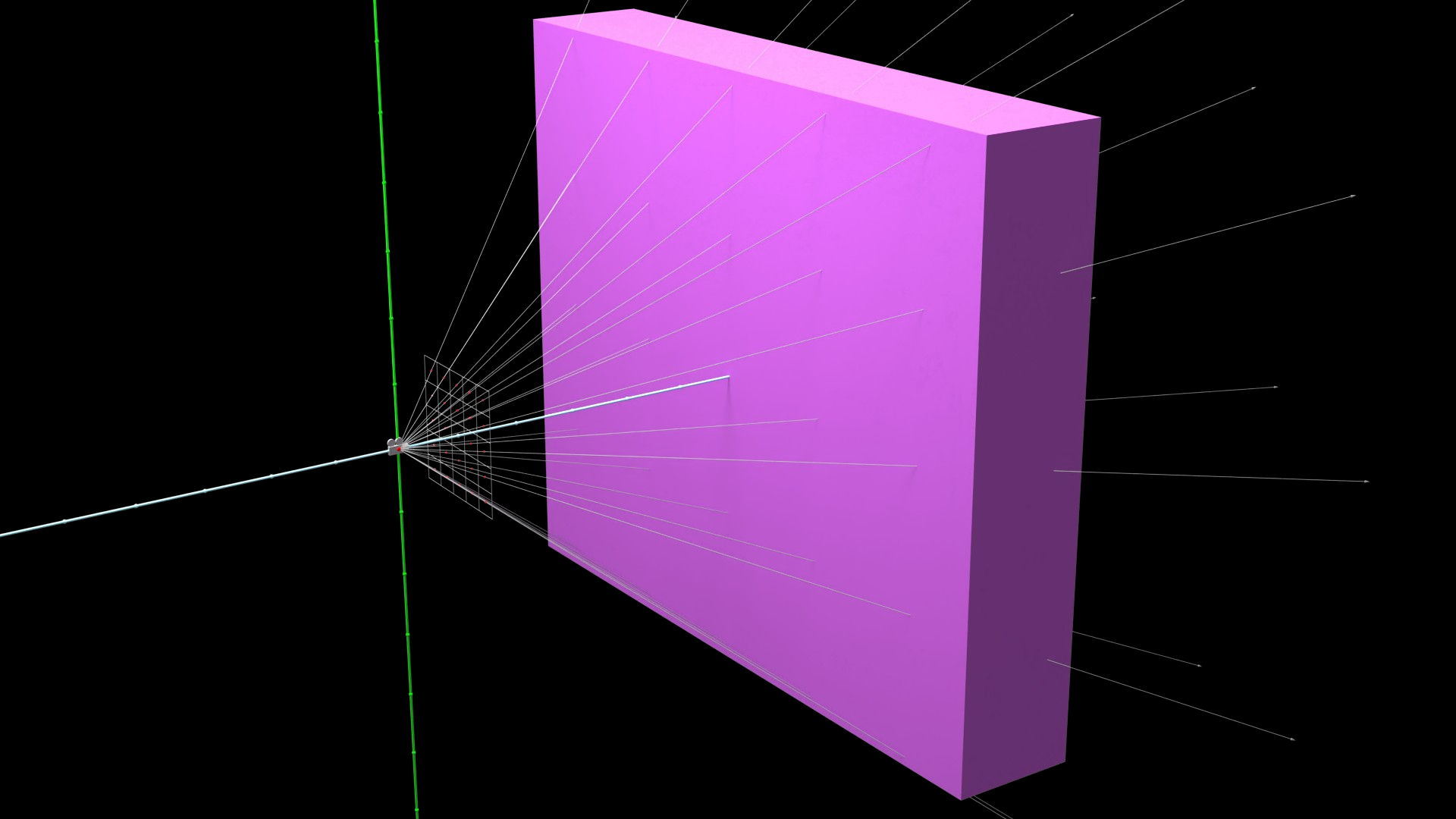


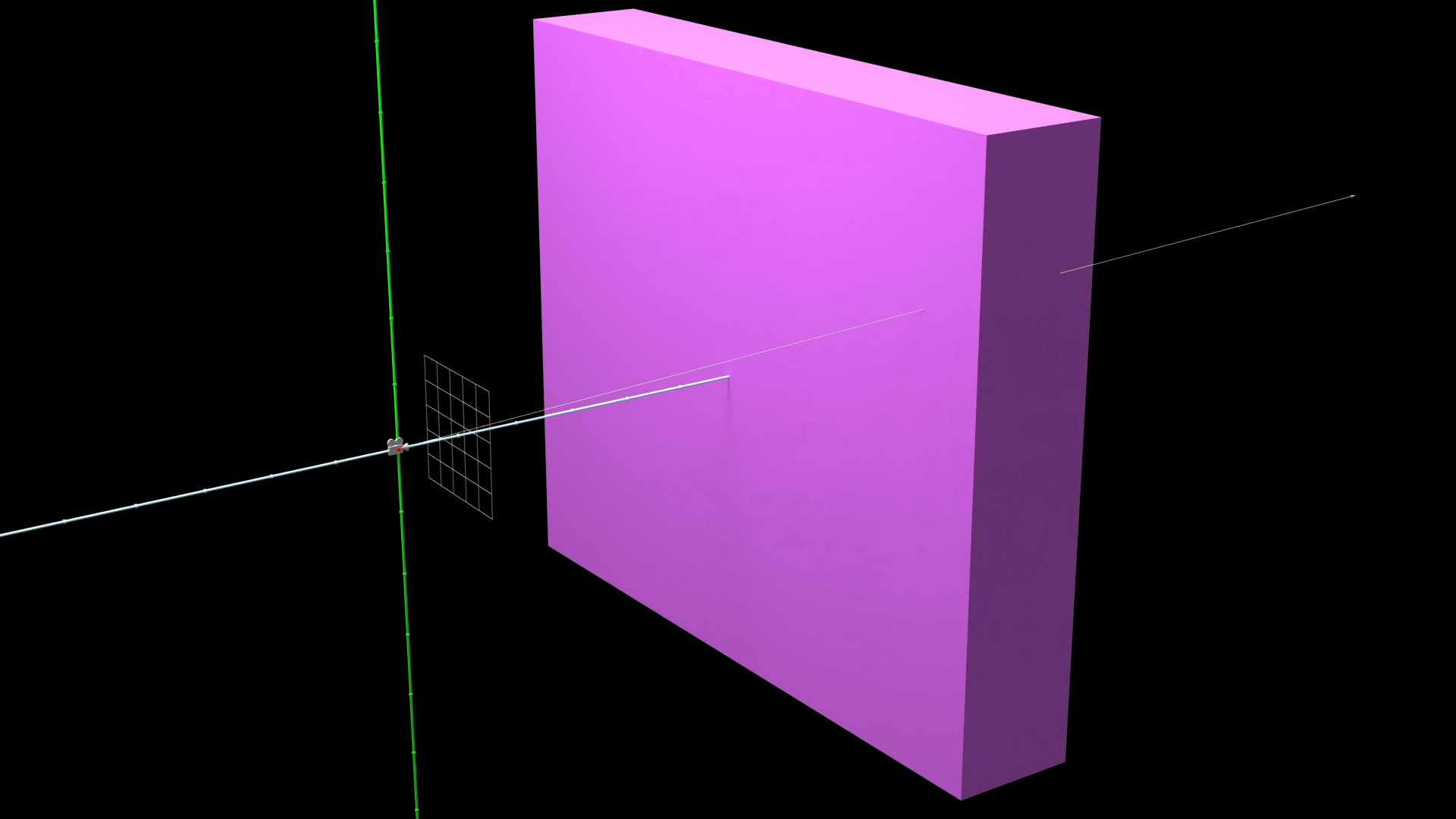


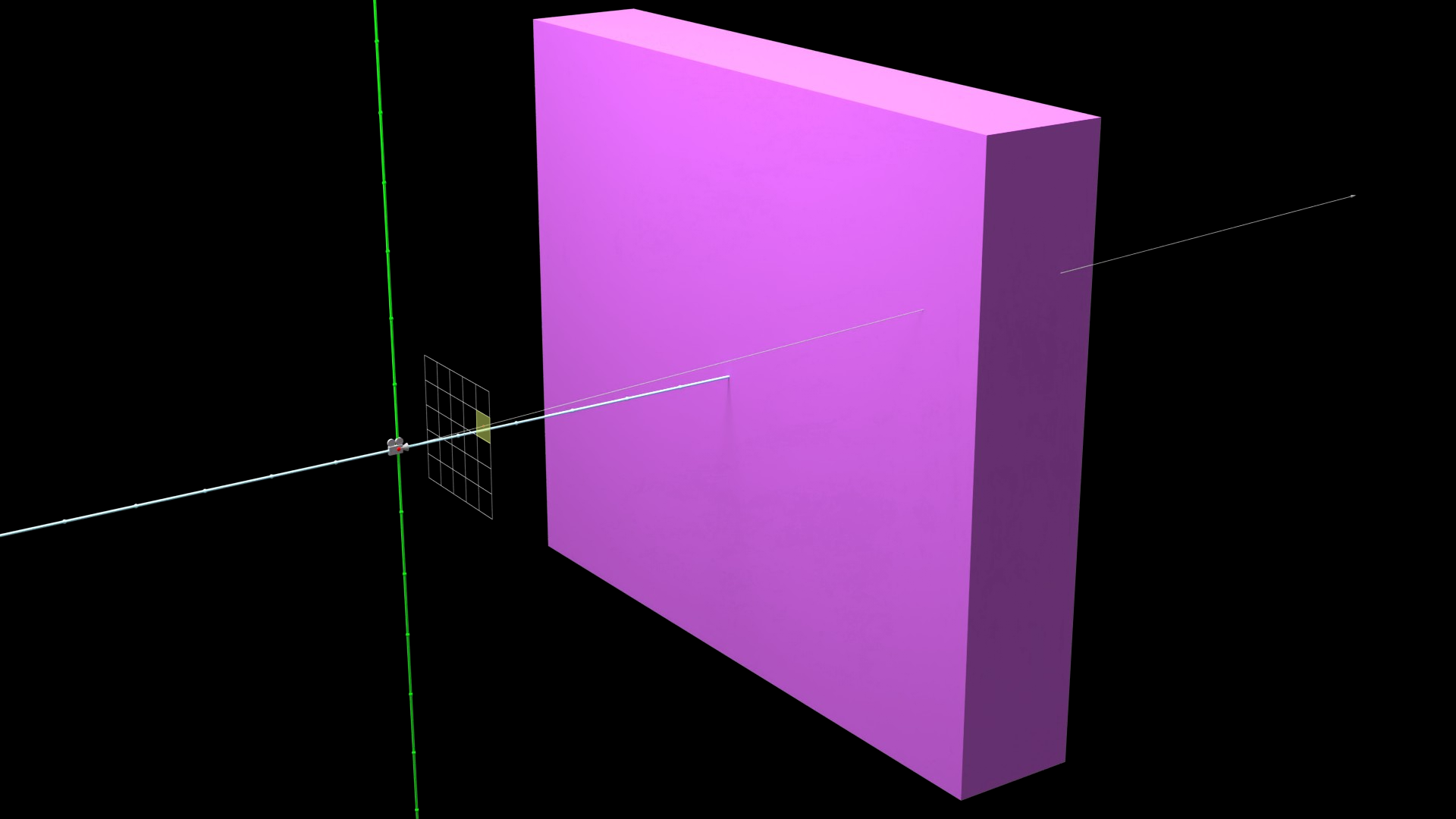


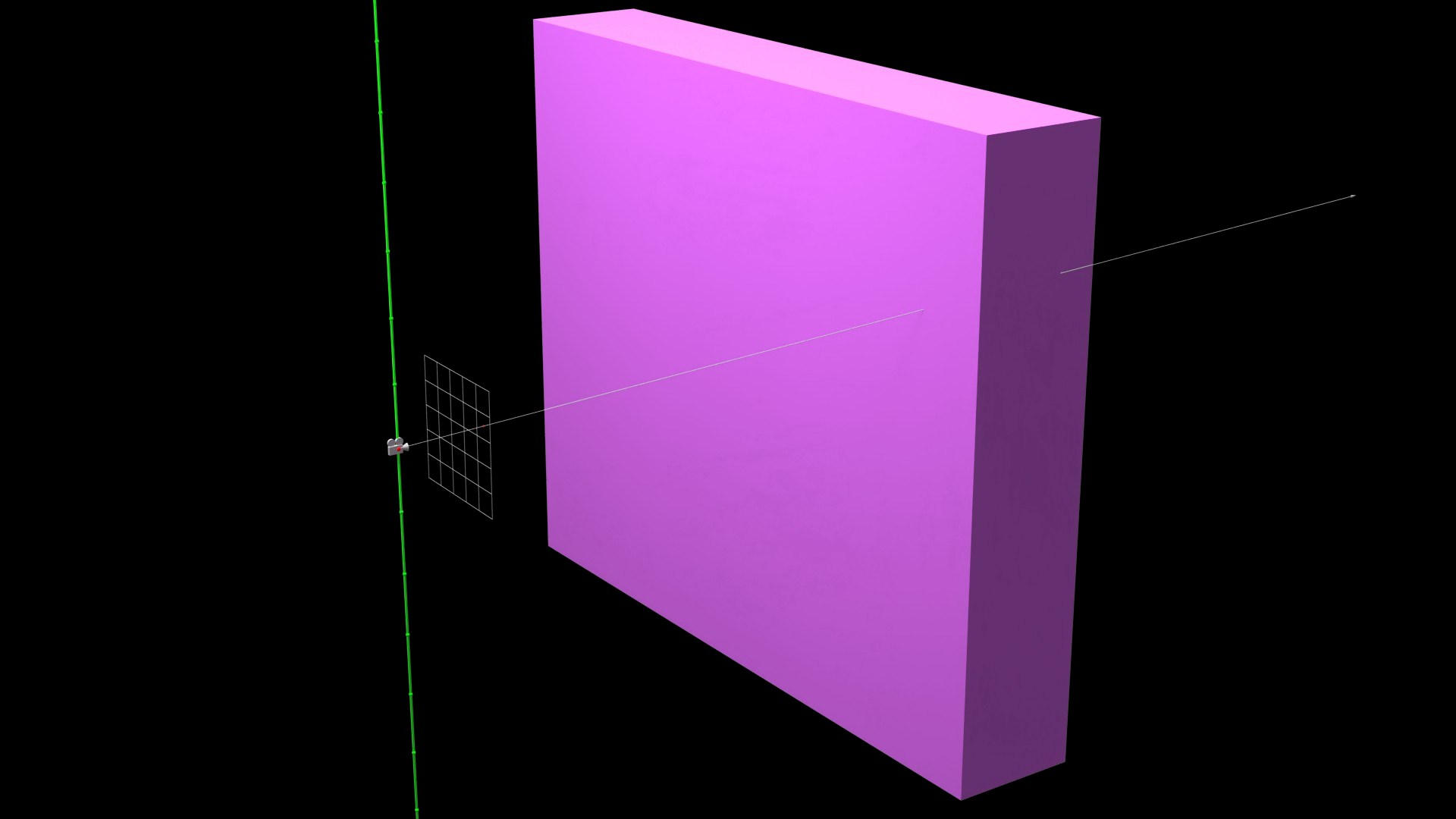
Use
Acceleration Structure

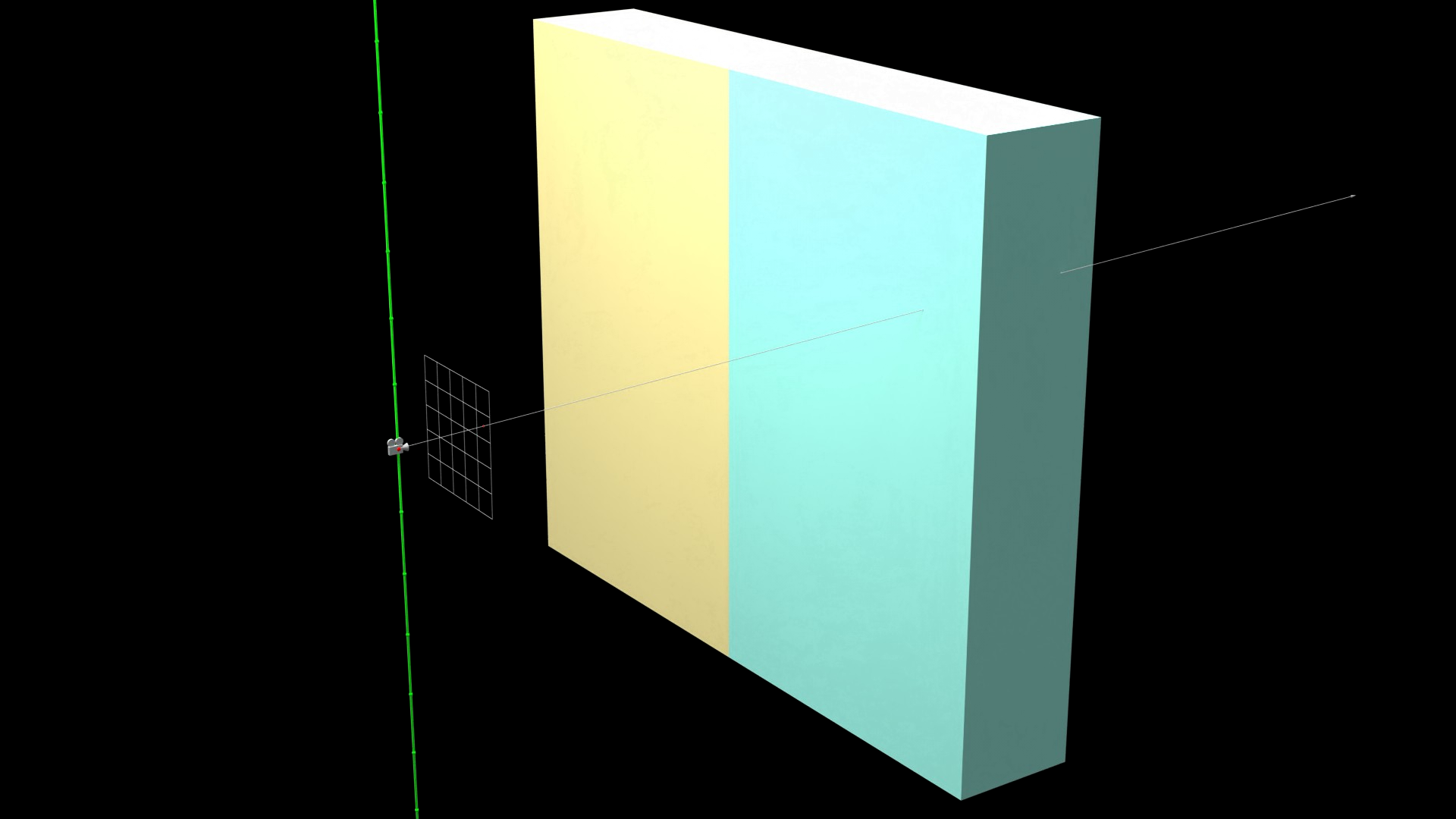


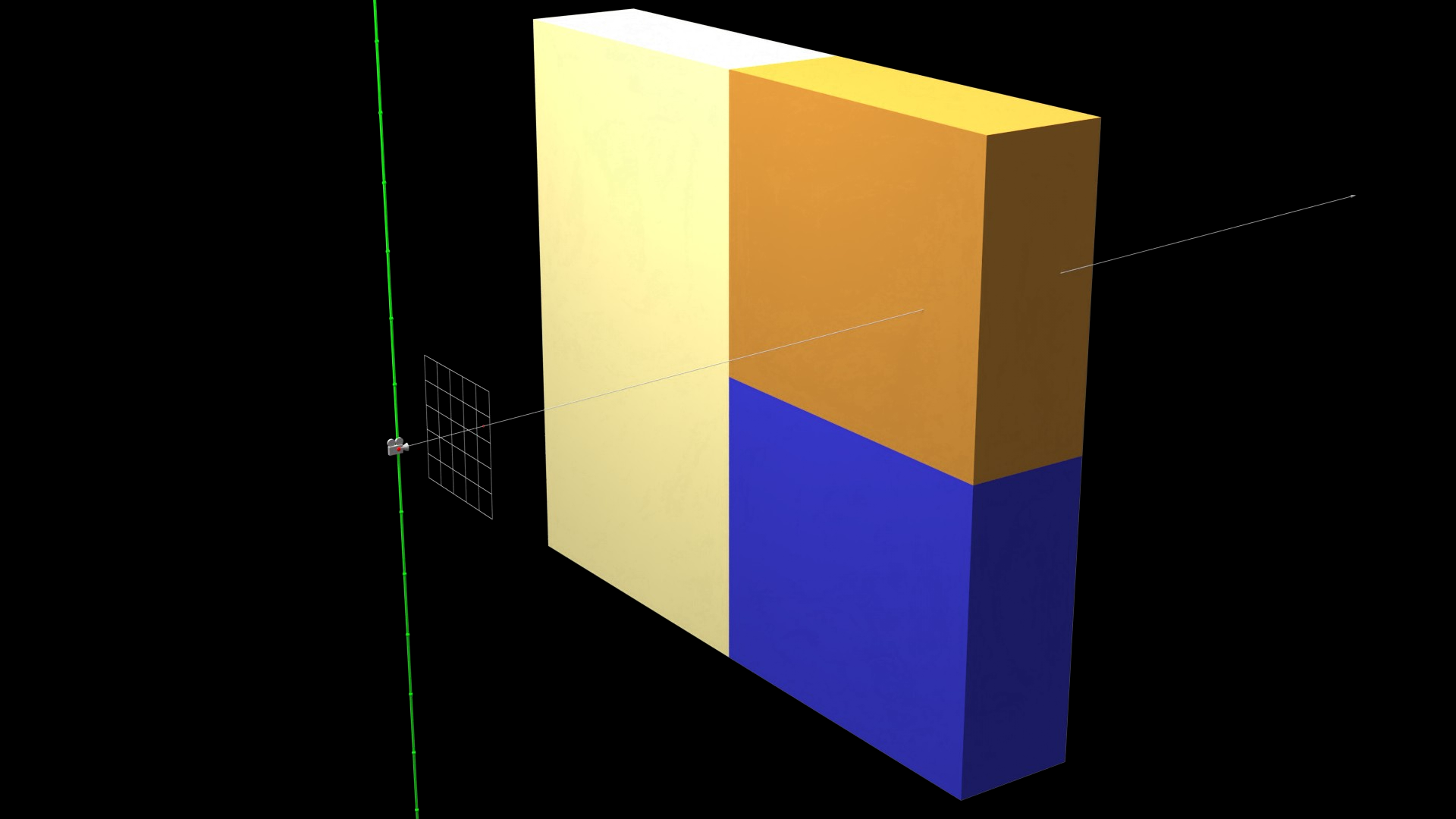


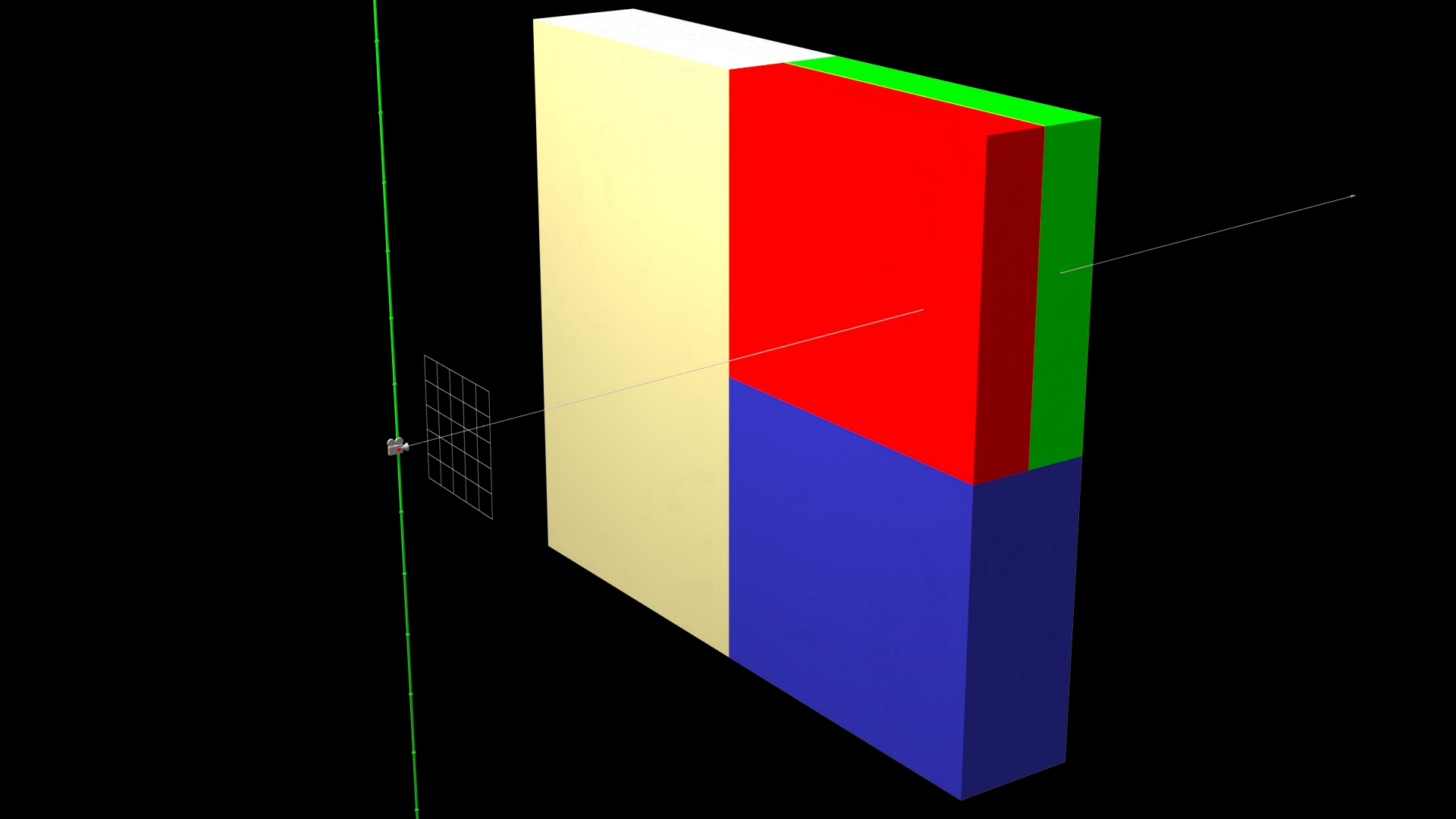


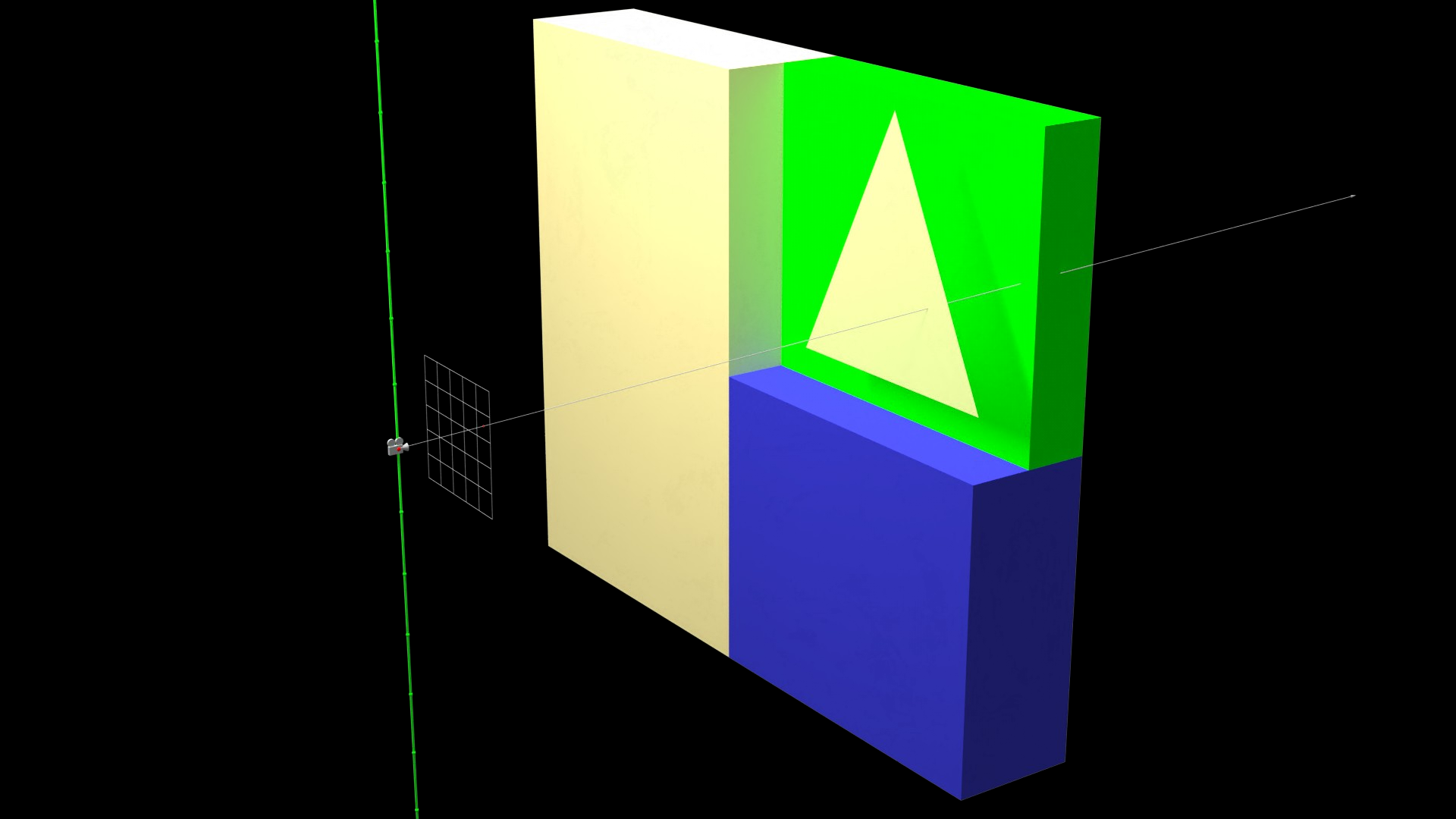


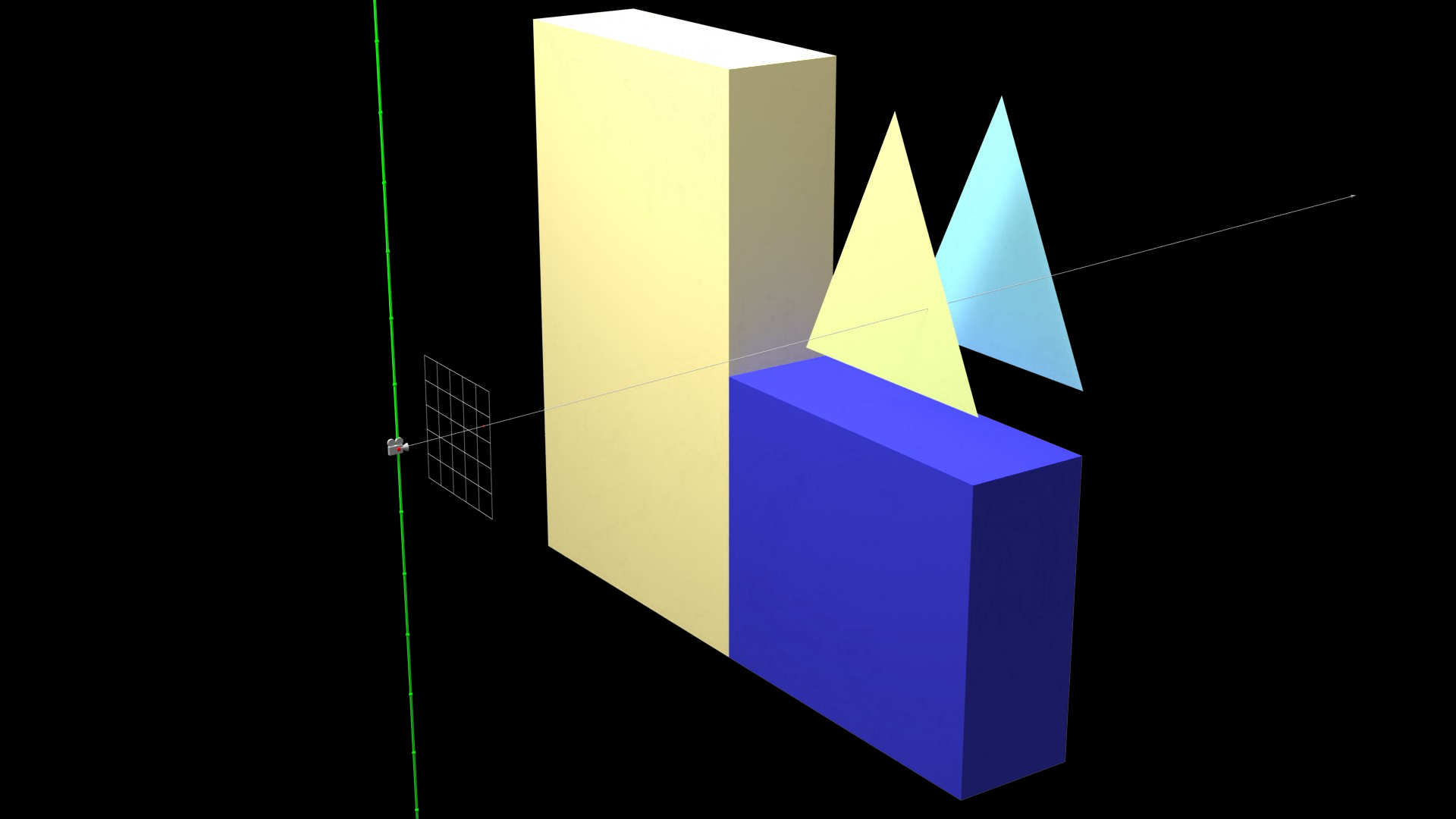




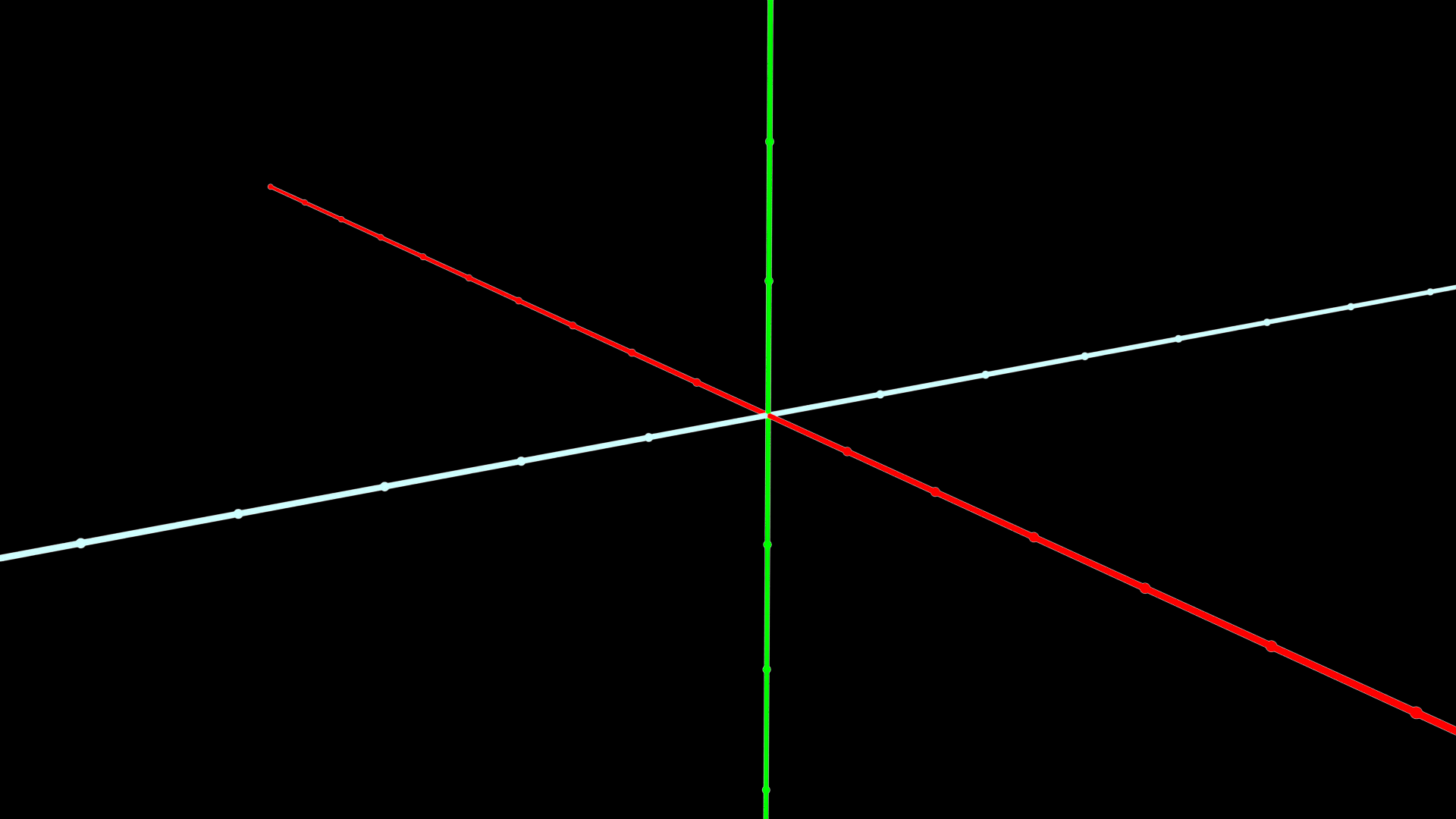


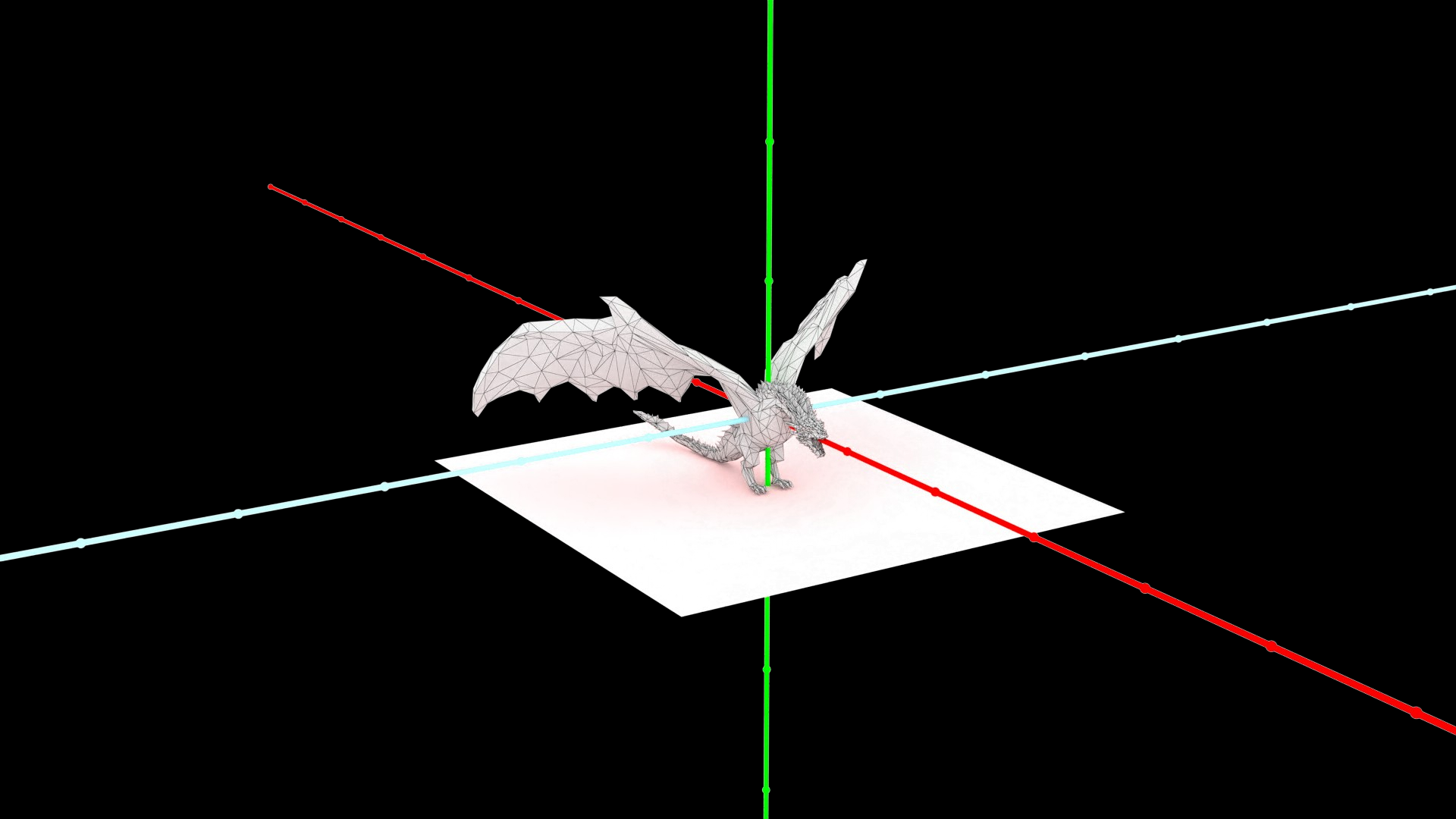


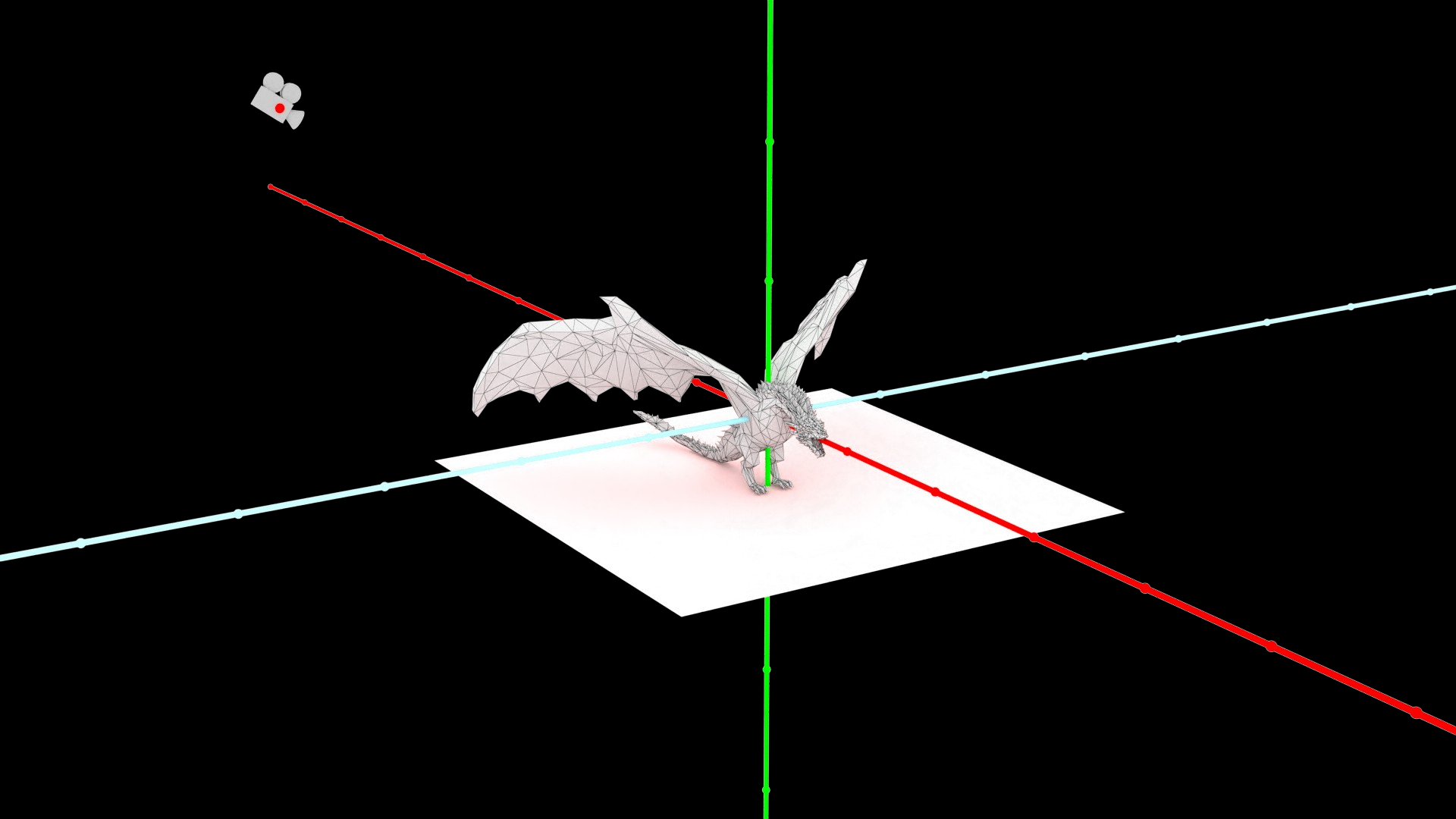


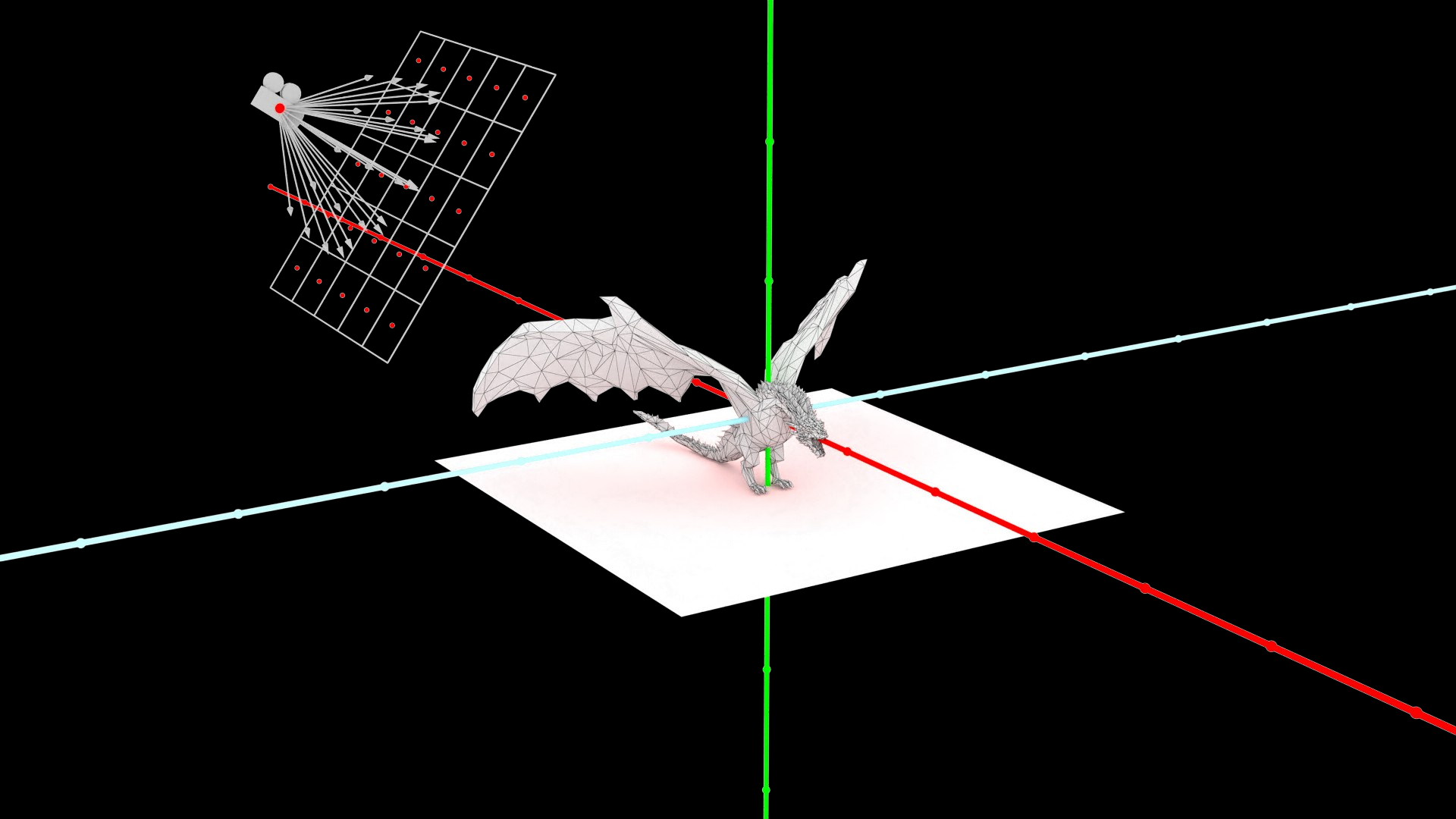


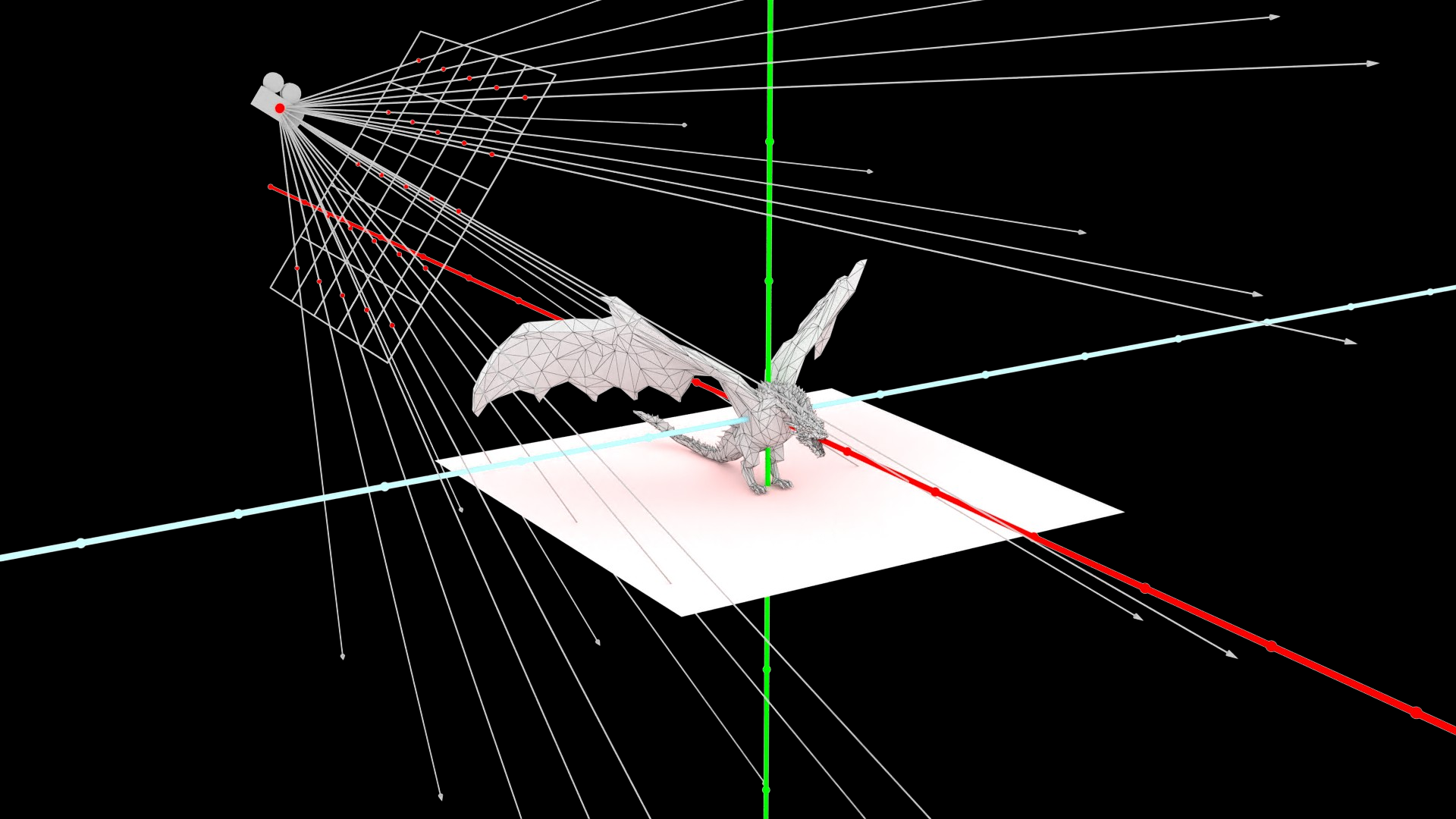
Slightly more complex scene

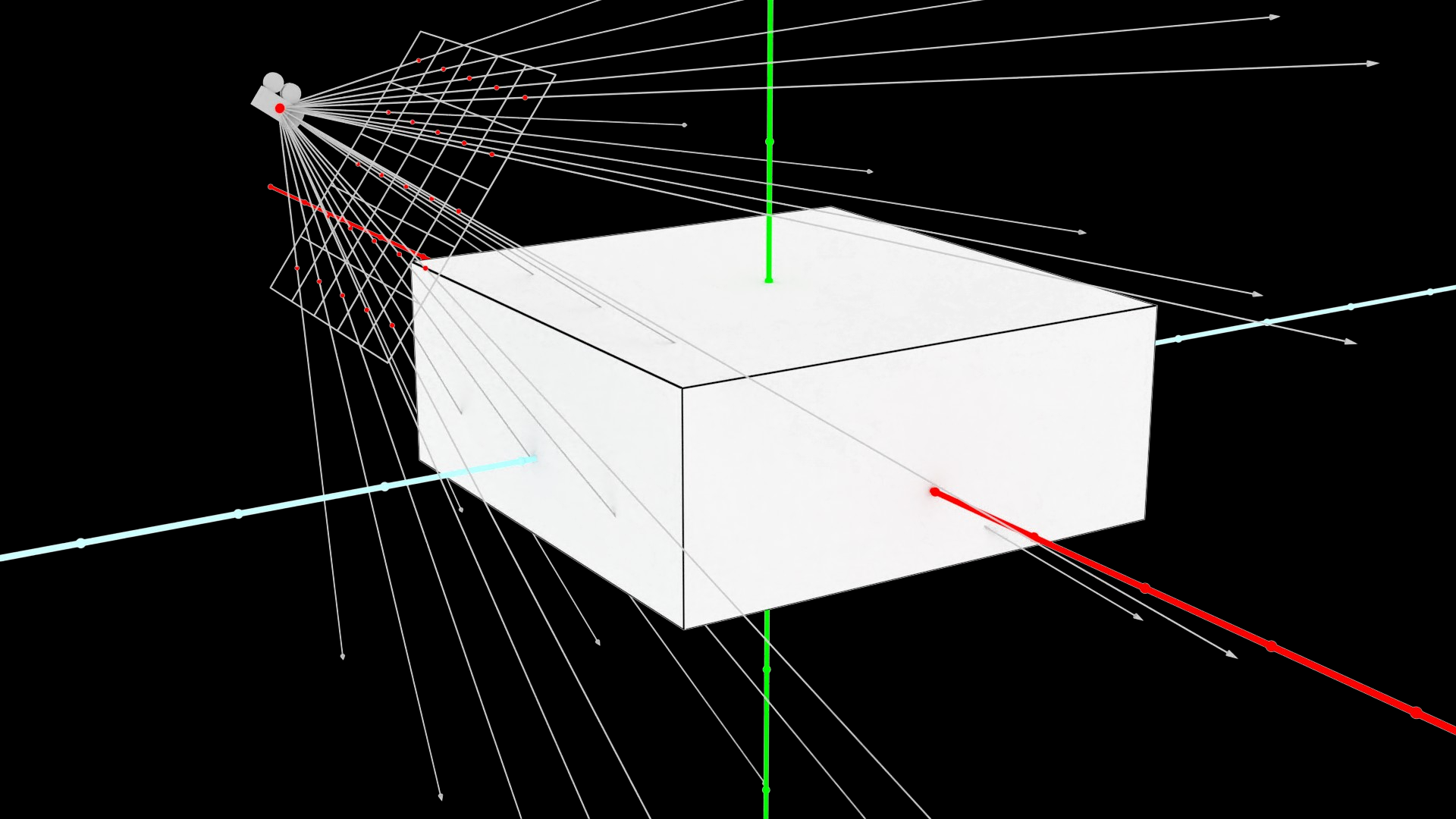


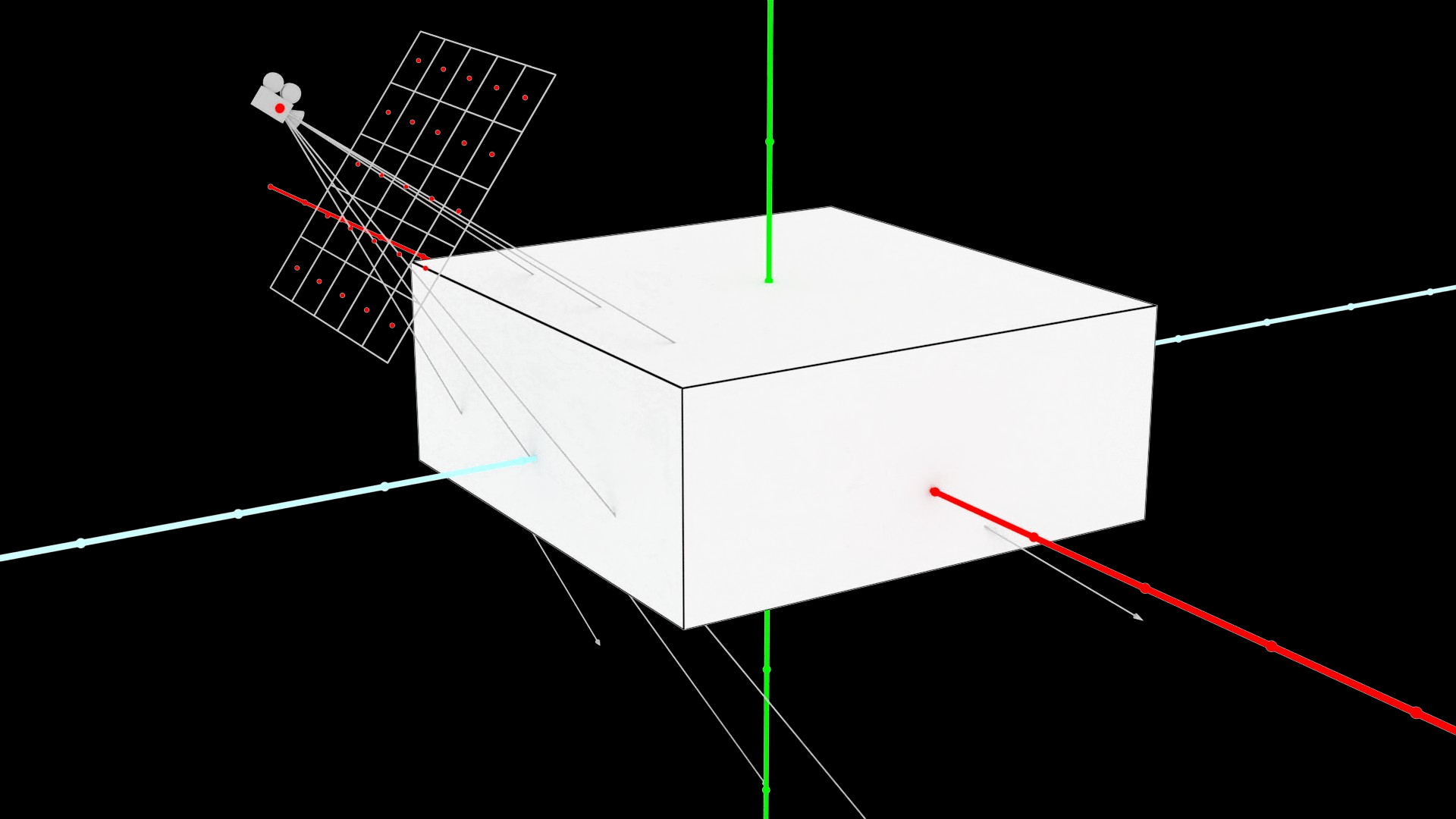


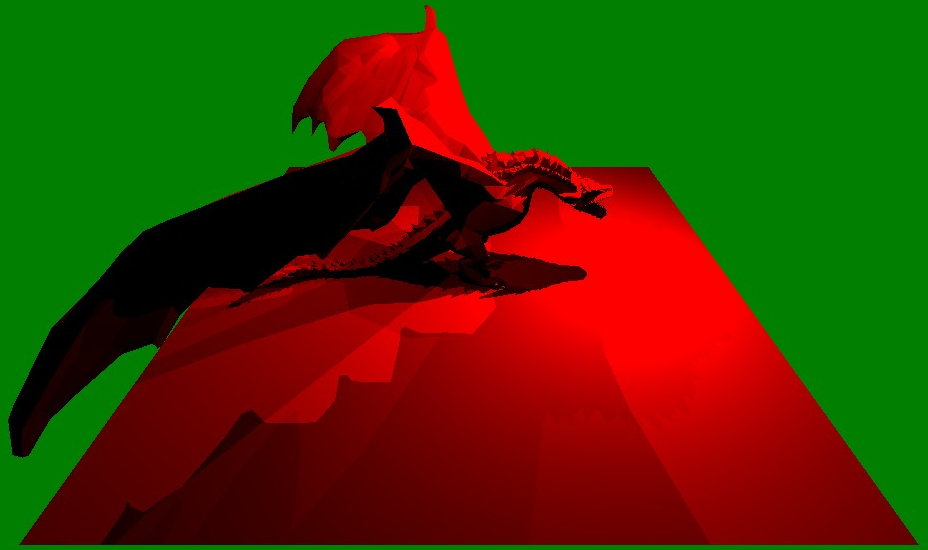


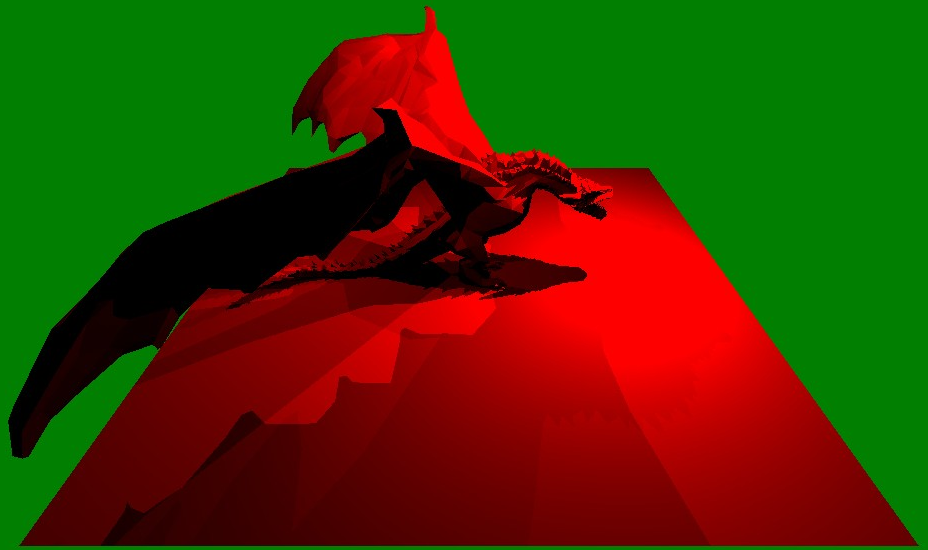




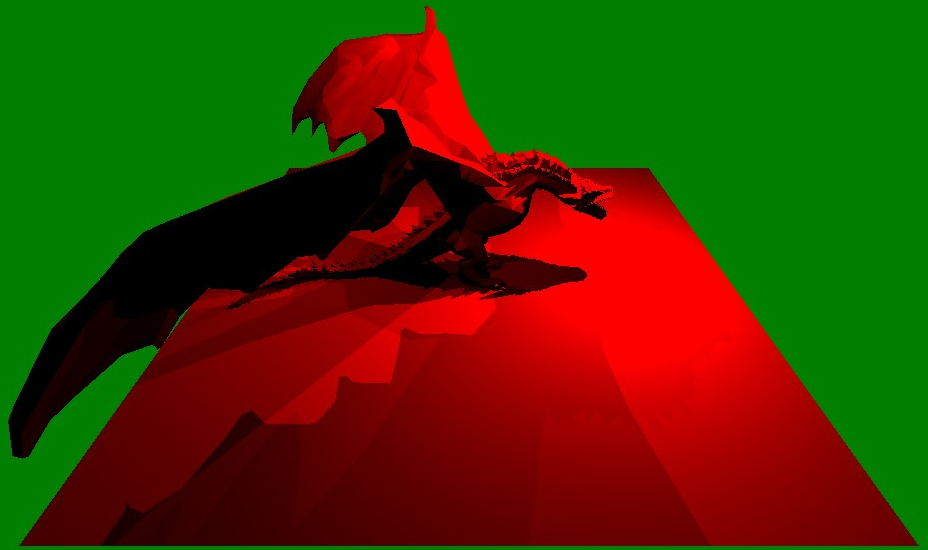




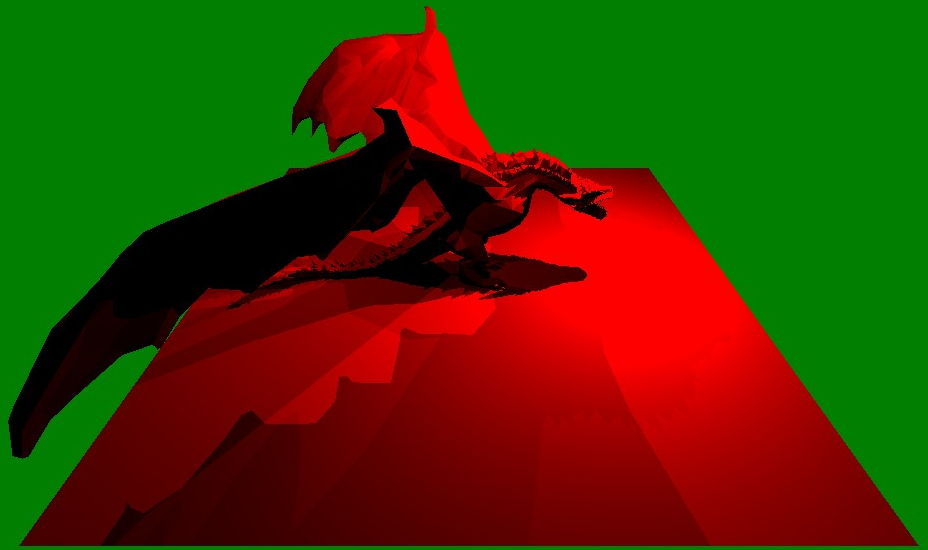




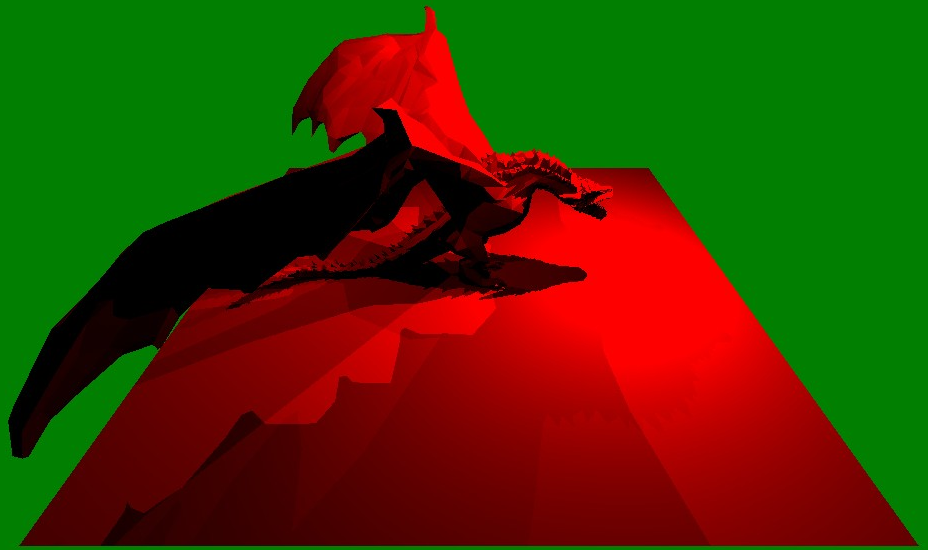
2 objects



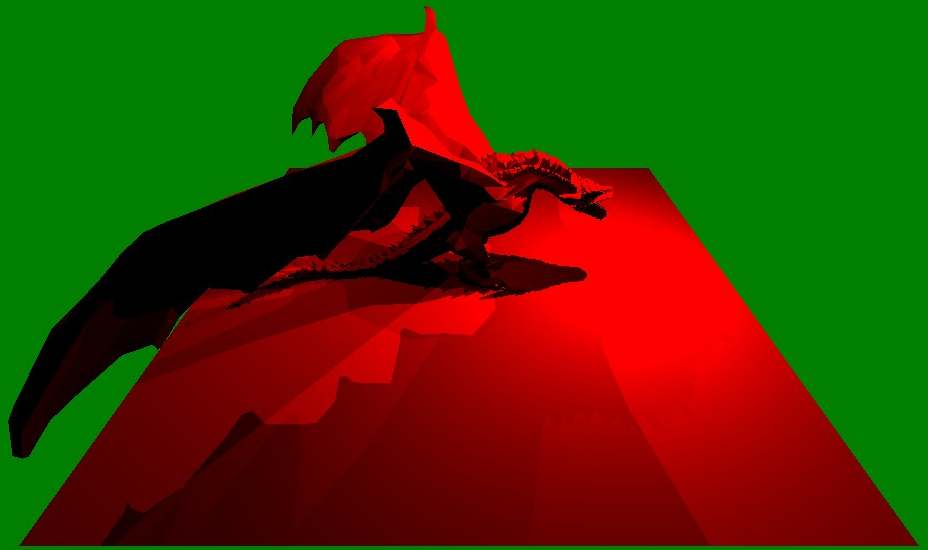
2 objects; **4014** triangles



2 objects; **4014** triangles; **1** diffuse material

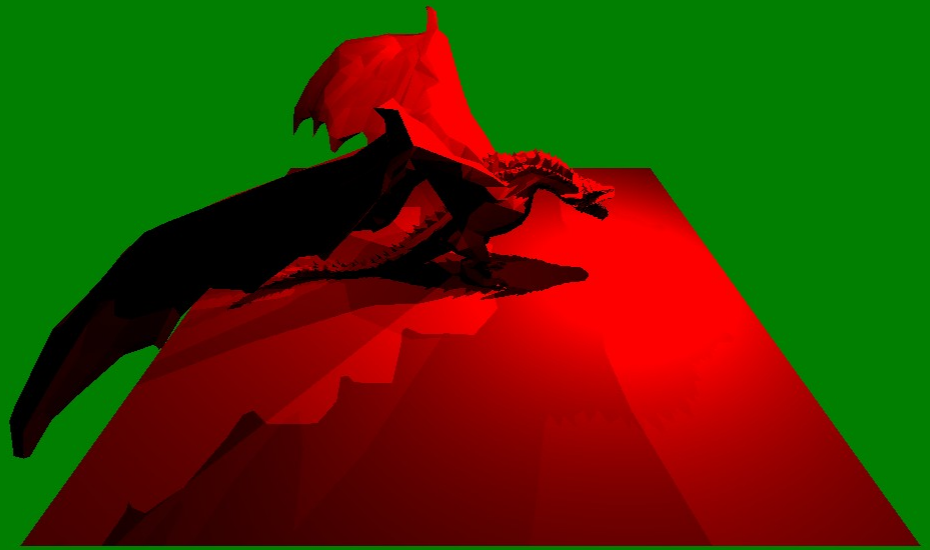


2 objects; **4014** triangles; **1** diffuse material; **4** lights



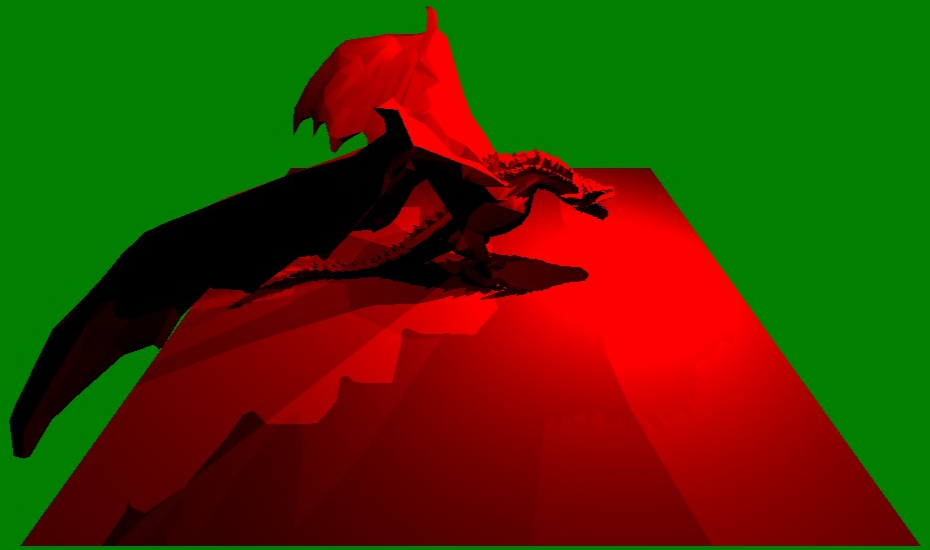
2 objects; **4014** triangles; **1** diffuse material; **4** lights; **1920**x**1080** resolution

Optimization	Render time In seconds



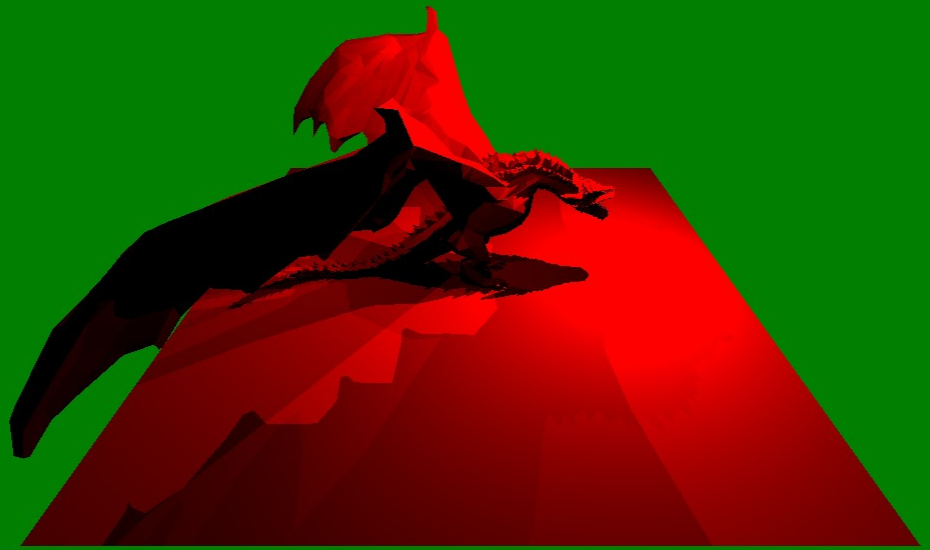
2 objects; **4014** triangles; **1** diffuse material; **4** lights; **1920**x**1080** resolution

Optimization	Render time In seconds
None	536.86



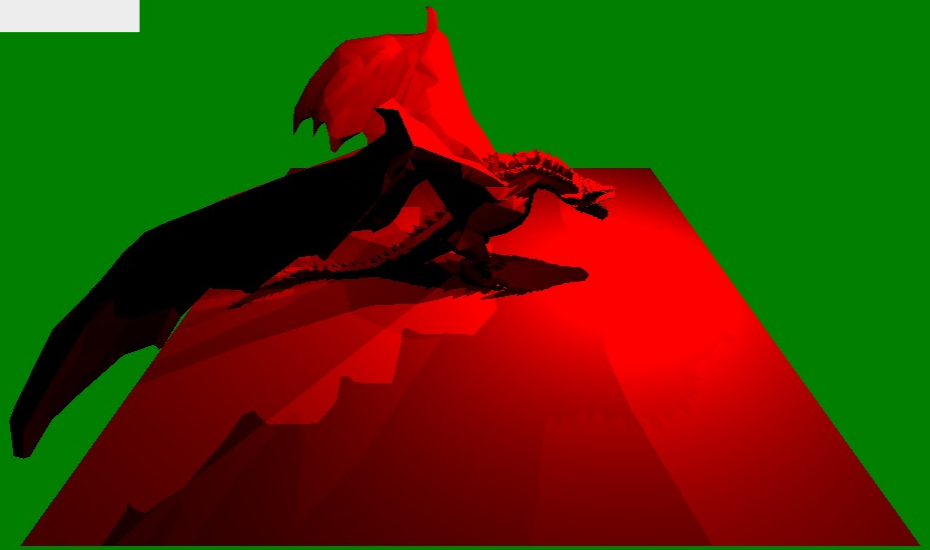
2 objects; **4014** triangles; **1** diffuse material; **4** lights; **1920**x**1080** resolution

Optimization	Render time In seconds
None	536.86
Regions rendering	98.93



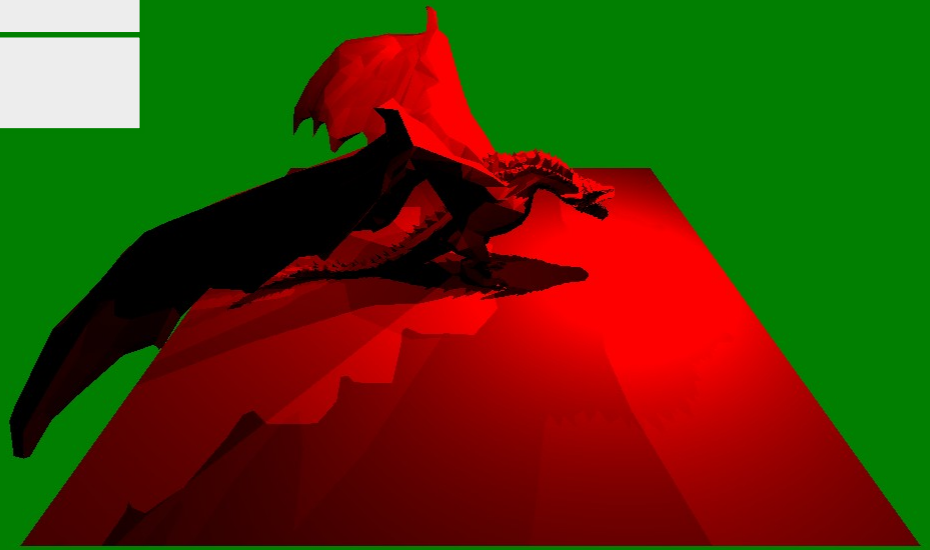
2 objects; **4014** triangles; **1** diffuse material; **4** lights; **1920**x**1080** resolution

Optimization	Render time In seconds
None	536.86
Regions rendering	98.93
Buckets rendering	52.45



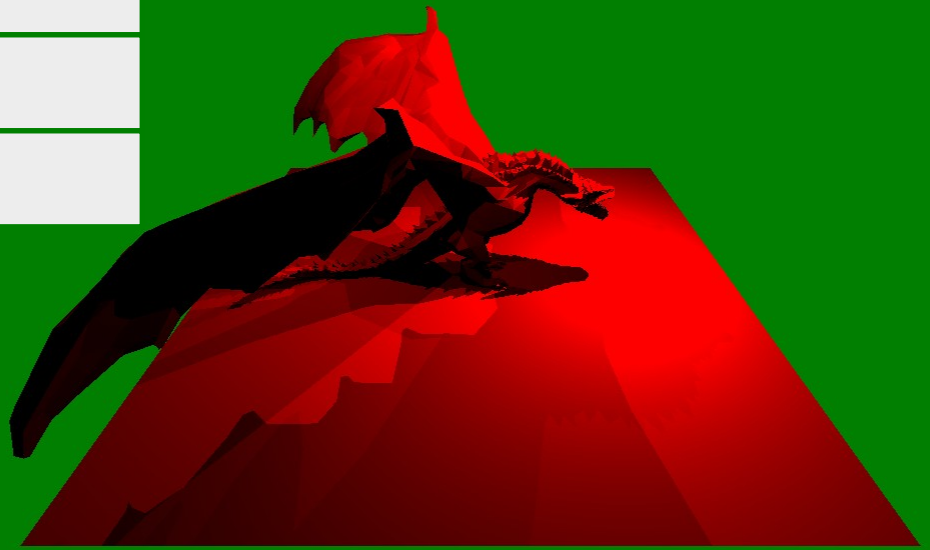
2 objects; **4014** triangles; **1** diffuse material; **4** lights; **1920**x**1080** resolution

Optimization	Render time In seconds
None	536.86
Regions rendering	98.93
Buckets rendering	52.45
Bounding Box	24.95



2 objects; **4014** triangles; **1** diffuse material; **4** lights; **1920**x**1080** resolution

Optimization	Render time In seconds
None	536.86
Regions rendering	98.93
Buckets rendering	52.45
Bounding Box	24.95
KD tree	0.7



2 objects; **4014** triangles; **1** diffuse material; **4** lights; **1920**x**1080** resolution

Acceleration data structures

Multiple Importance Sampling

Russian roulette

Optimizations

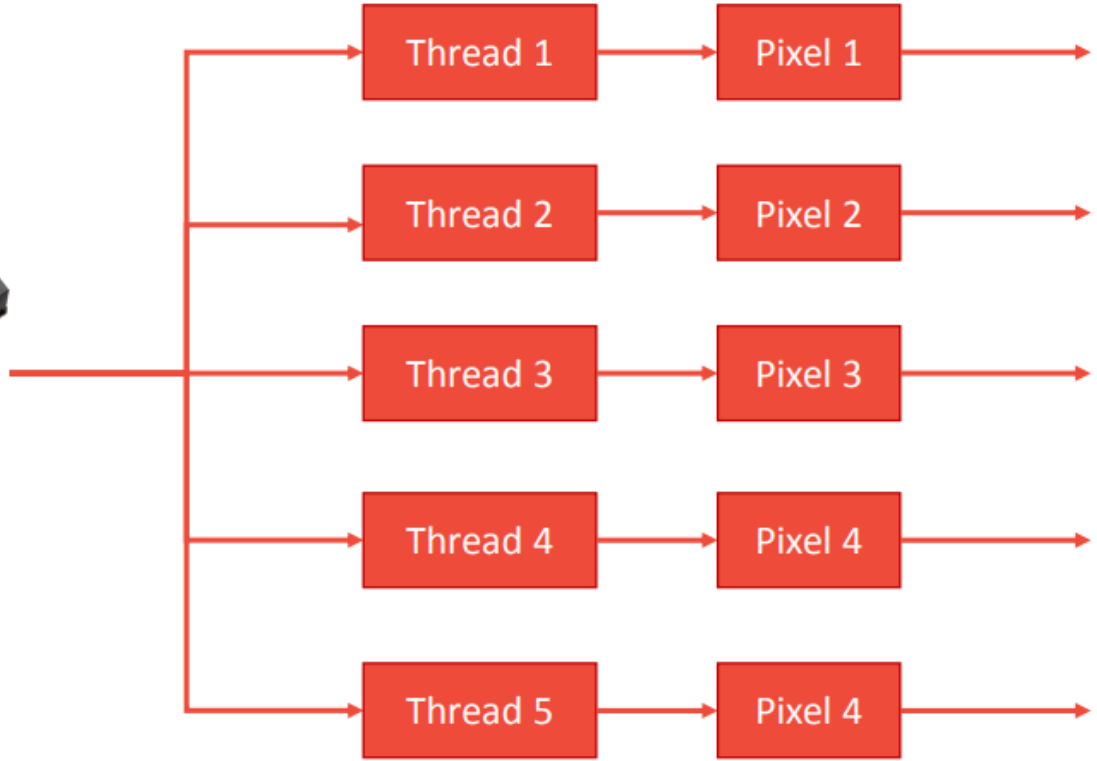
...

Path guiding

Hardware accelerations

Shadow queues

GTX 1080Ti
NVIDIA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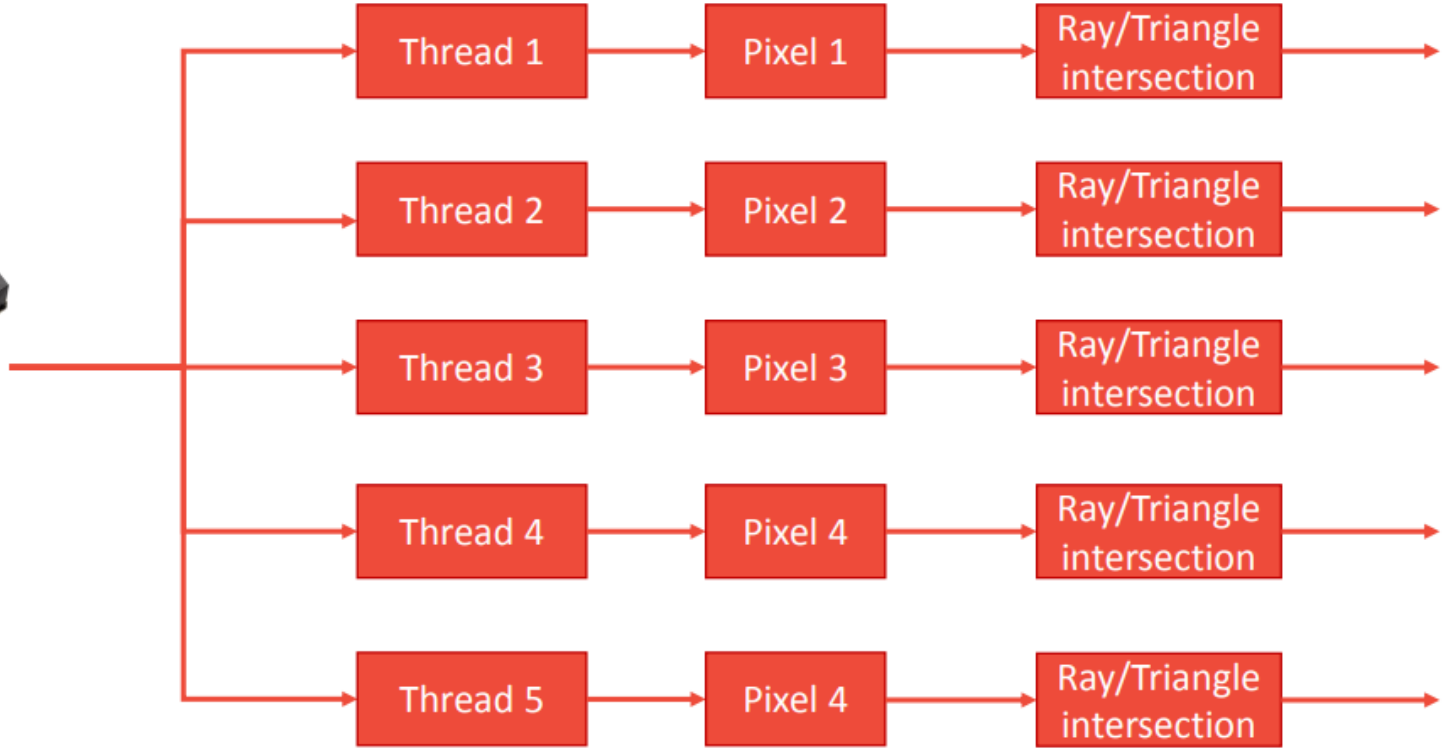
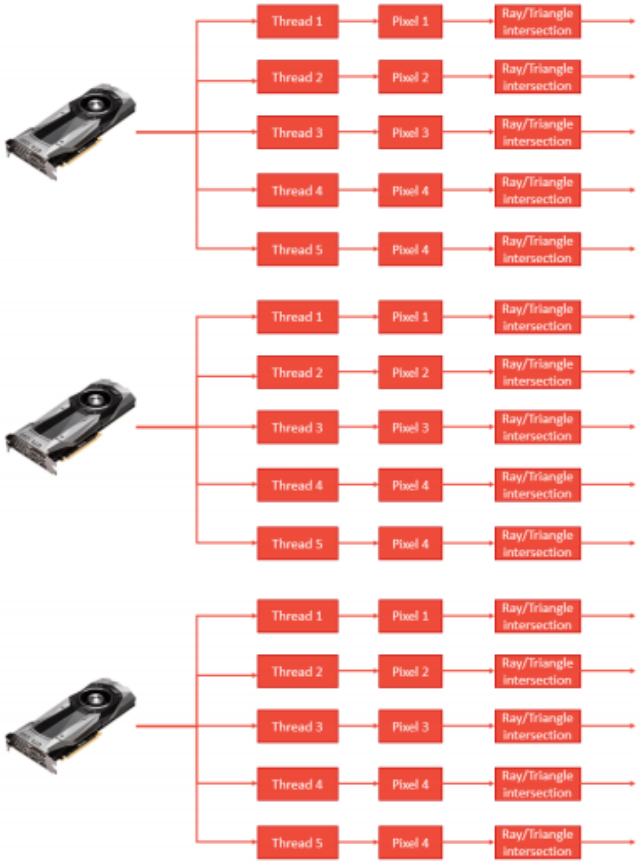
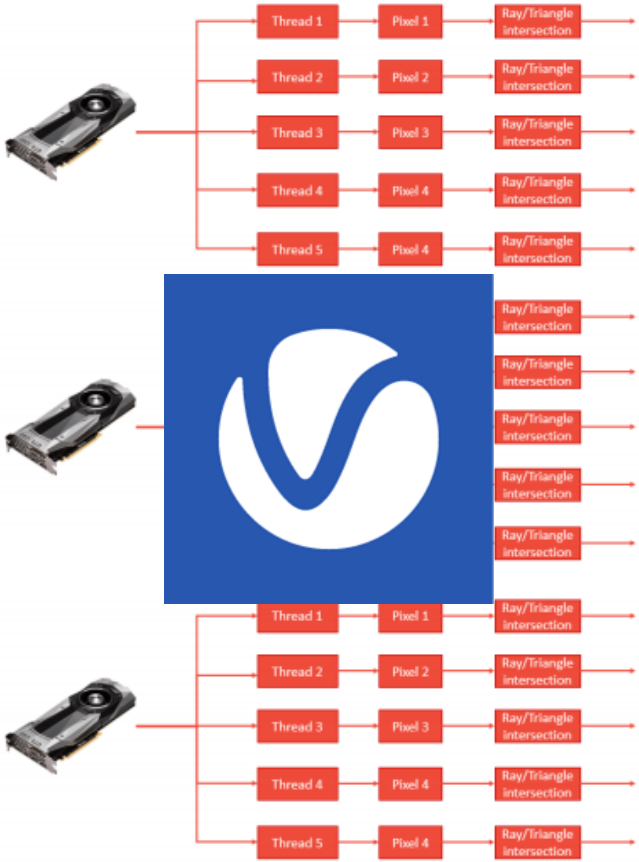
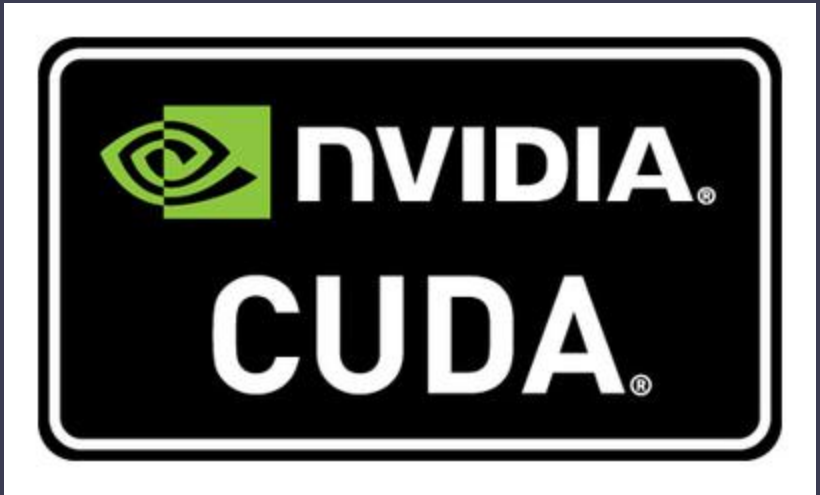
Pixel 1
Thread 2
Pixel 2
Thread 3
Pixel 3
Thread 4
Pixel 4
Thread 5
Pixel 4

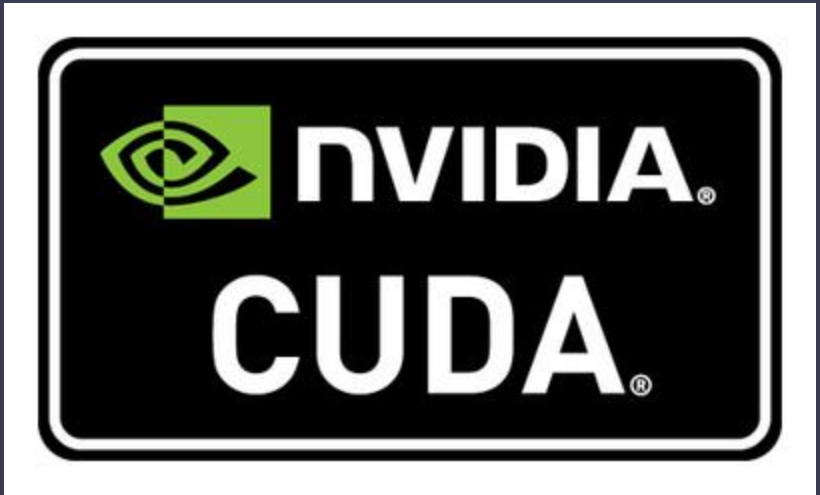

Thread 1
Pixel 1
Ray/Triangle intersection
Thread 2
Pixel 2
Ray/Triangle intersection
Thread 3
Pixel 3
Ray/Triangle intersection
Thread 4
Pixel 4
Ray/Triangle intersection
Thread 5
Pixel 4
Ray/Triangle intersection


Thread 1
Pixel 1
Ray/Triangle intersection
Thread 2
Pixel 2
Ray/Triangle intersection
Thread 3
Pixel 3
Ray/Triangle intersection
Thread 4
Pixel 4
Ray/Triangle intersection
Thread 5
Pixel 4
Ray/Triangle intersection
Thread 1
Pixel 1
Ray/Triangle intersection
Thread 2
Pixel 2
Ray/Triangle intersection
Thread 3
Pixel 3
Ray/Triangle intersection
Thread 4
Pixel 4
Ray/Triangle intersection
Thread 5
Pixel 4
Ray/Triangle intersection
Thread 1
Pixel 1
Ray/Triangle intersection
Thread 2
Pixel 2
Ray/Triangle intersection
Thread 3
Pixel 3
Ray/Triangle intersection
Thread 4
Pixel 4
Ray/Triangle intersection
Thread 5
Pixel 4
Ray/Triangle intersection

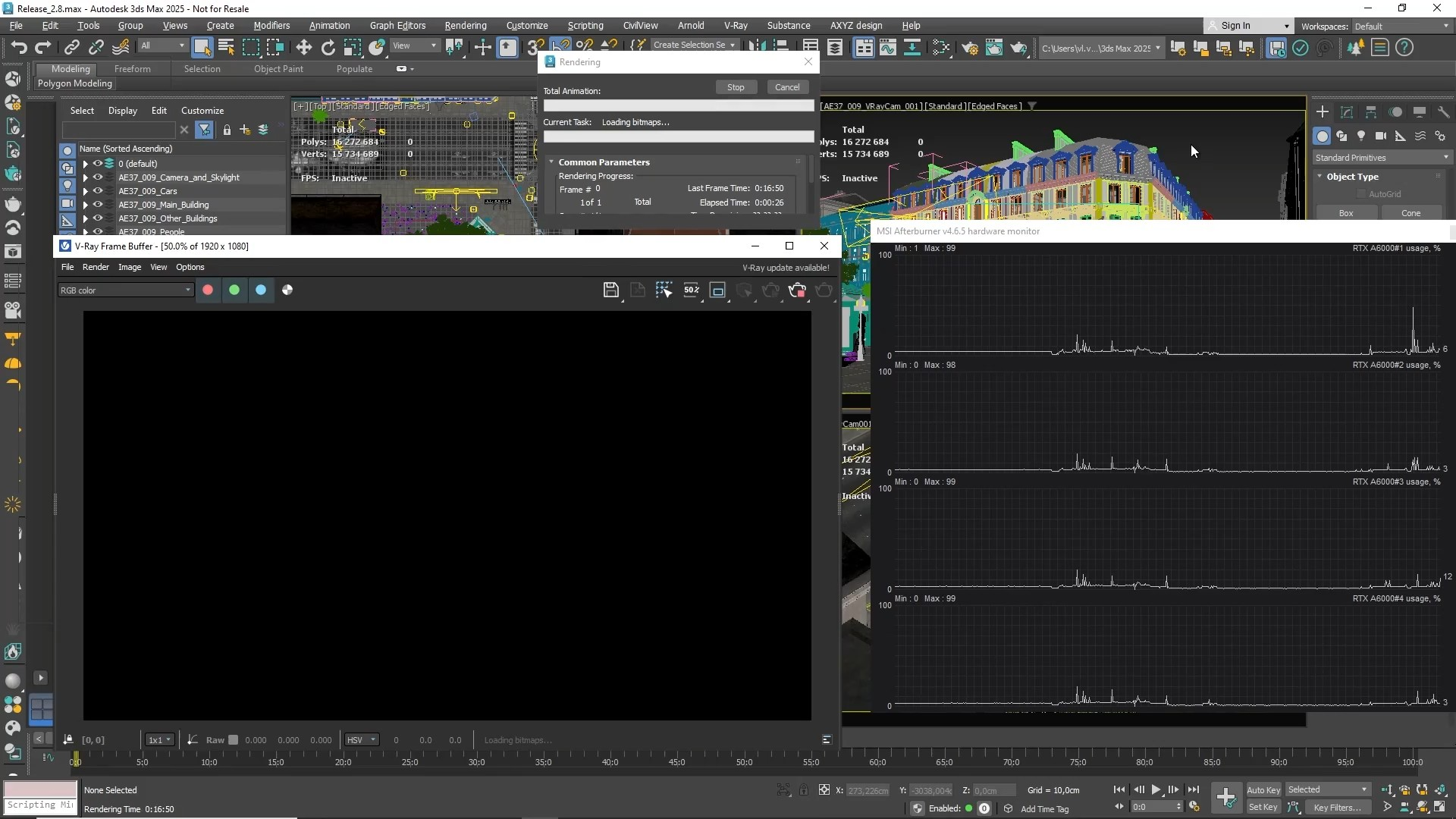

Thread 1
Pixel 1
Ray/Triangle intersection
Thread 2
Pixel 2
Ray/Triangle intersection
Thread 3
Pixel 3
Ray/Triangle intersection
Thread 4
Pixel 4
Ray/Triangle intersection
Thread 5
Pixel 4
Ray/Triangle intersection
Ray/Triangle intersection
Ray/Triangle intersection
Ray/Triangle intersection
Ray/Triangle intersection
Ray/Triangle intersection
Thread 1
Pixel 1
Ray/Triangle intersection
Thread 2
Pixel 2
Ray/Triangle intersection
Thread 3
Pixel 3
Ray/Triangle intersection
Thread 4
Pixel 4
Ray/Triangle intersection
Thread 5
Pixel 4
Ray/Triangle intersection

V-Ray GPU
2009


NVIDIA
CUDA


NVIDIA
CUDA

OpenCL™


Release_2.8.max - Autodesk 3ds Max 2025 - Not for Resale
File Edit Tools Group Views Create Modifiers Animation Graph Editors Rendering Customize Scripting CivilView Arnold V-Ray Substance AXYZ design Help
Sign In
Workspaces: Default
Modeling Freeform Selection Object Paint Populate
Polygon Modeling
Select Display Edit Customize
Name (Sorted Ascending)
0 (default)
AE37_009_Camera_and_Skylight
AE37_009_Cars
AE37_009_Main_Building
AE37_009_Other_Buildings
AE37_009_People
[+] [Top] [Standard] [Edged Faces]
Total
Polys: 16 272 684 0
Verts: 15 734 689 0
FPS: Inactive
Rendering
Total Animation:
Stop
Cancel
Current Task: Loading bitmaps...
Common Parameters
Rendering Progress:
Frame # 0
1 of 1
Total
Last Frame Time: 0:16:50
Elapsed Time: 0:00:26
[AE37_009_VRayCam_001] [Standard] [Edged Faces]
Standard Primitives
Object Type
AutoGrid
Box
Cone
V-Ray Frame Buffer - [50.0% of 1920 x 1080]
File Render Image View Options
V-Ray update available!
RGB color
MSI Afterburner v4.6.5 hardware monitor
Min : 1 Max : 99
RTX A6000#1 usage, %
Min : 0 Max : 98
RTX A6000#2 usage, %
Min : 0 Max : 99
RTX A6000#3 usage, %
Min : 0 Max : 99
RTX A6000#4 usage, %
None Selected
Rendering Time 0:16:50
Grid = 10,0cm
Add Time Tag
Auto Key
Set Key
Key Filters...

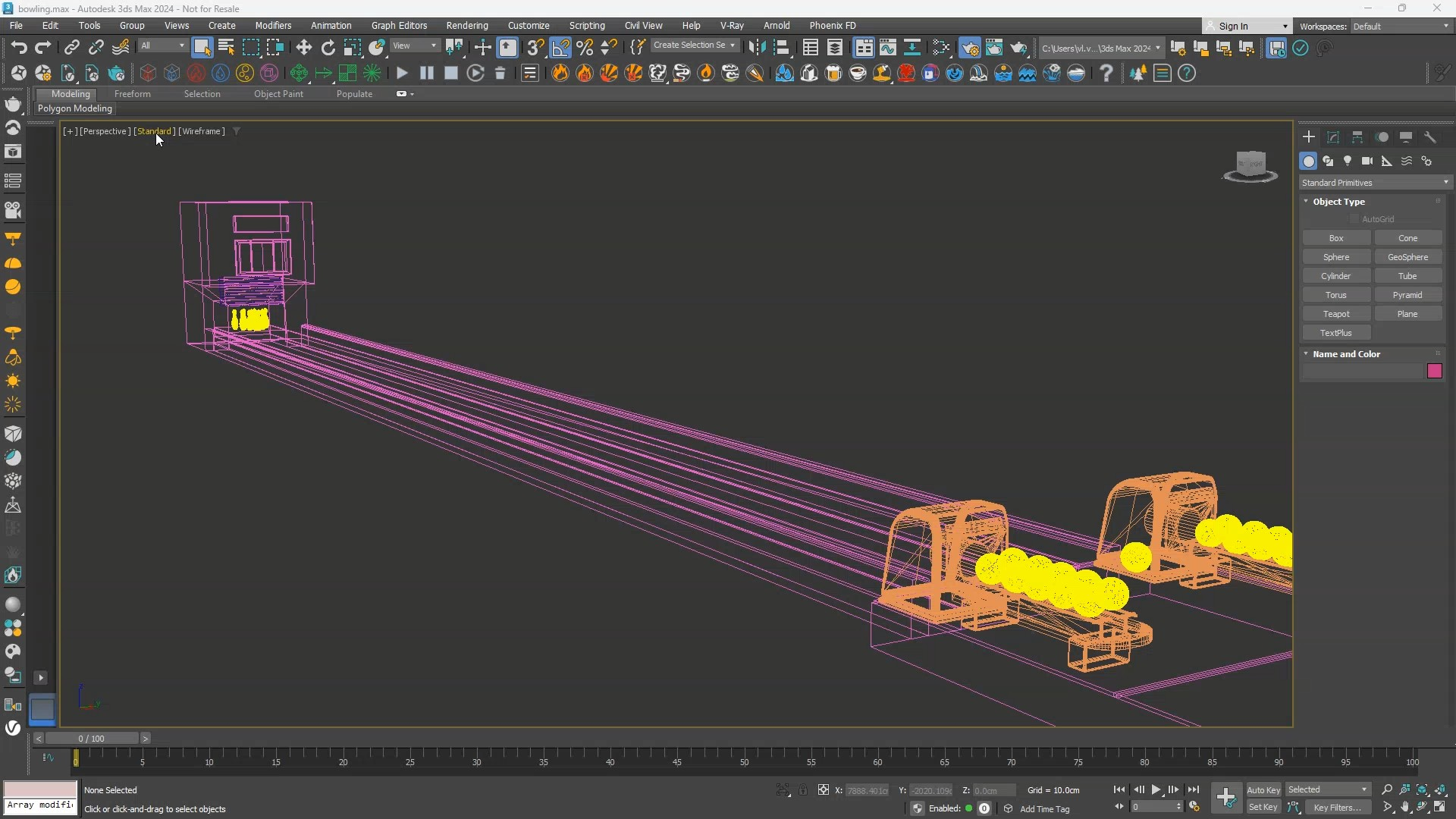
Real Time

Real Time Rendering

Real Time
Hardware accelerated
Rendering

Fast photorealistic feedback

V-Ray CPU IPR demo


bowling.max - Autodesk 3ds Max 2024 - Not for Resale
File Edit Tools Group Views Create Modifiers Animation Graph Editors Rendering Customize Scripting Civil View Help V-Ray Arnold Phoenix FD
Sign In
Workspaces: Default
Modeling Freeform Selection Object Paint Populate
Polygon Modeling
[+] [Perspective] [Standard] [Wireframe]
Standard Primitives
Object Type
AutoGrid
Box Cone
Sphere GeoSphere
Cylinder Tube
Torus Pyramid
Teapot Plane
TextPlus
Name and Color
0 / 100
None Selected
Click or click-and-drag to select objects
Array modifi
Grid = 10.0cm
Add Time Tag
Auto Key
Set Key
Key Filters...

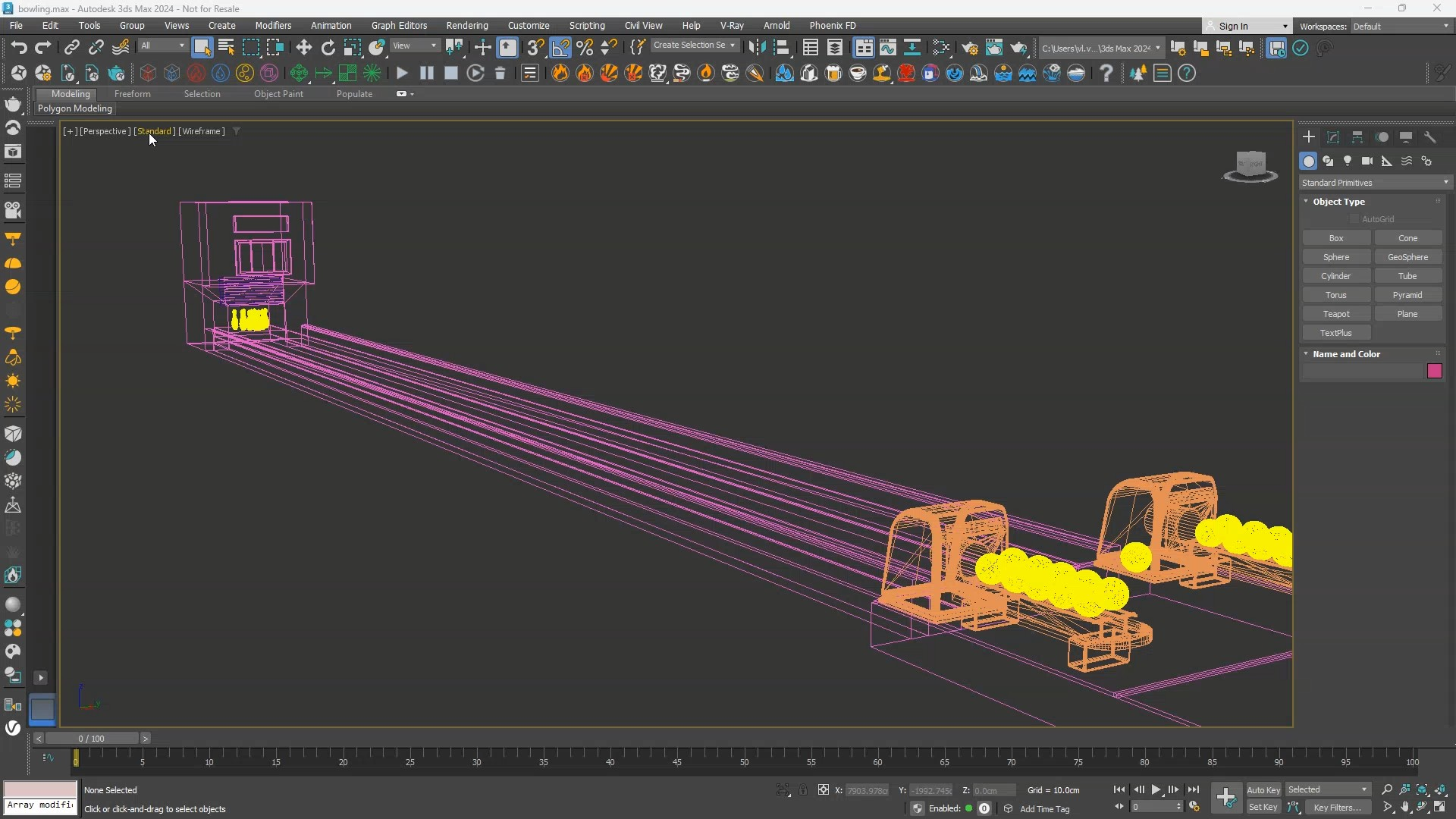
Limitations

Sending images to GPU for RT

GPU

Fast photorealistic feedback

V-Ray GPU IPR demo


bowling.max - Autodesk 3ds Max 2024 - Not for Resale
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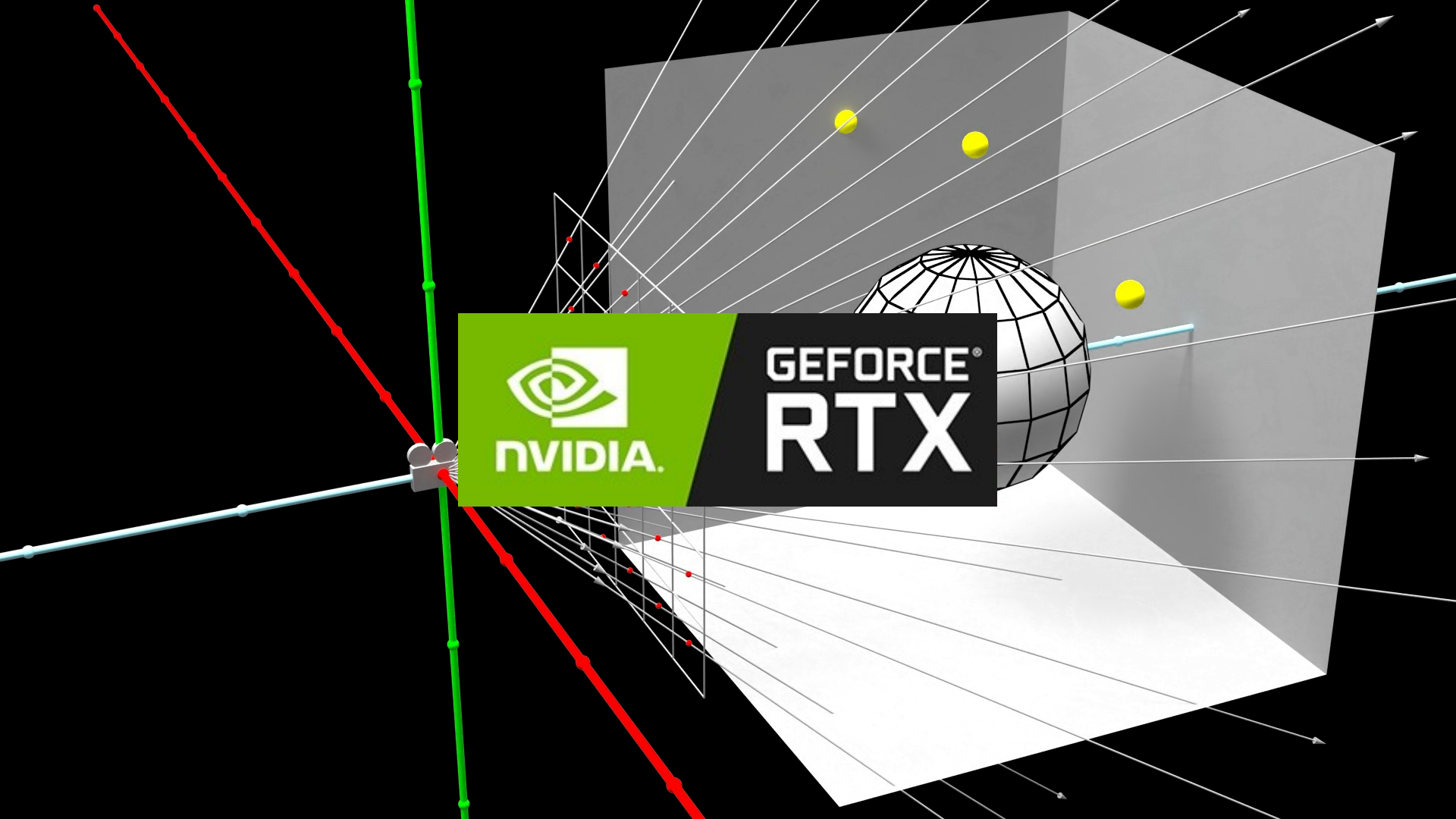
Name and Color
0 / 100
None Selected
Click or click-and-drag to select objects
Grid = 10.0cm
Add Time Tag
Auto Key
Set Key
Key Filters...

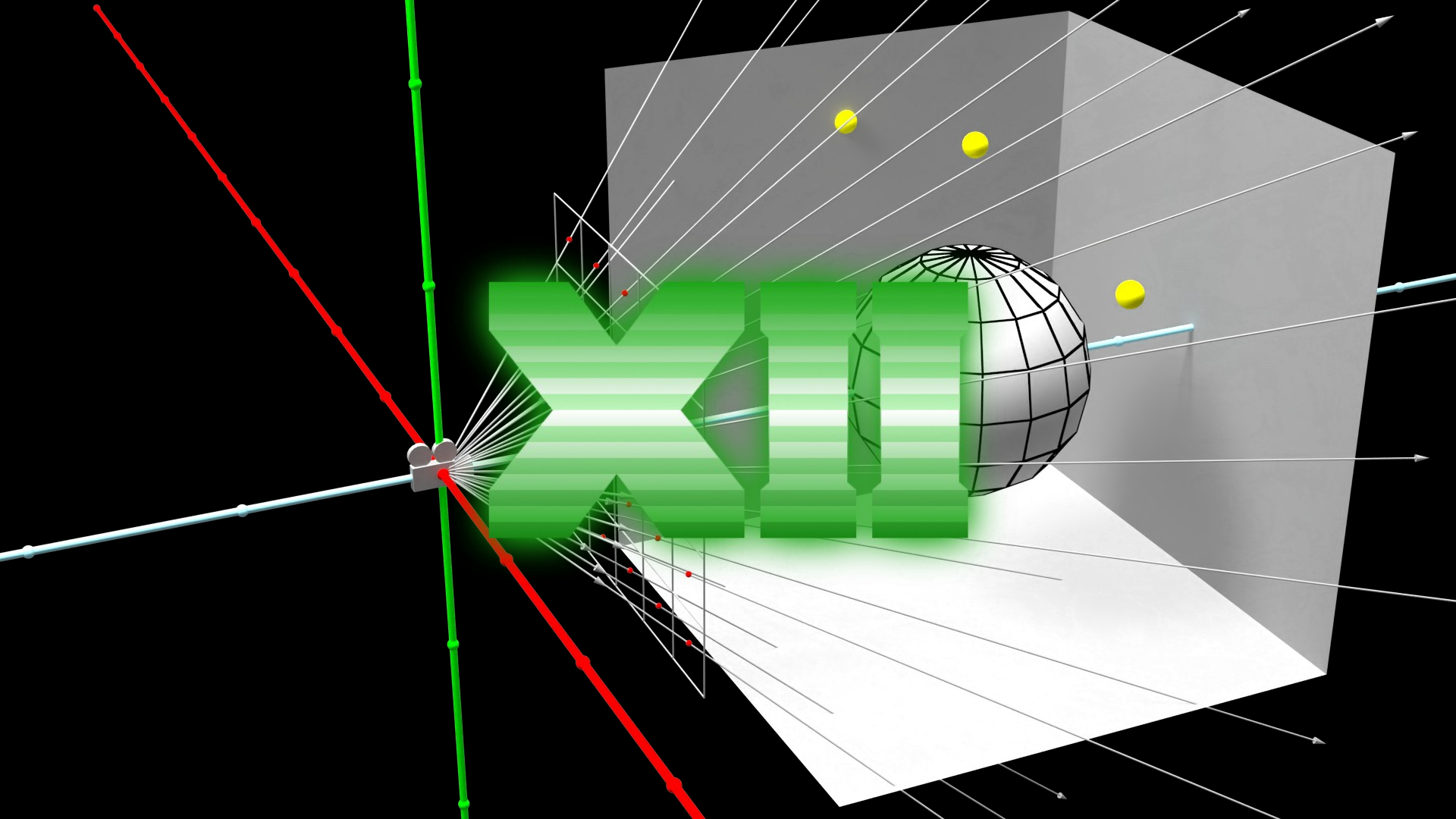
Real Time Ray Tracing!

Hardware accelerated Ray Tracing in Real Time!

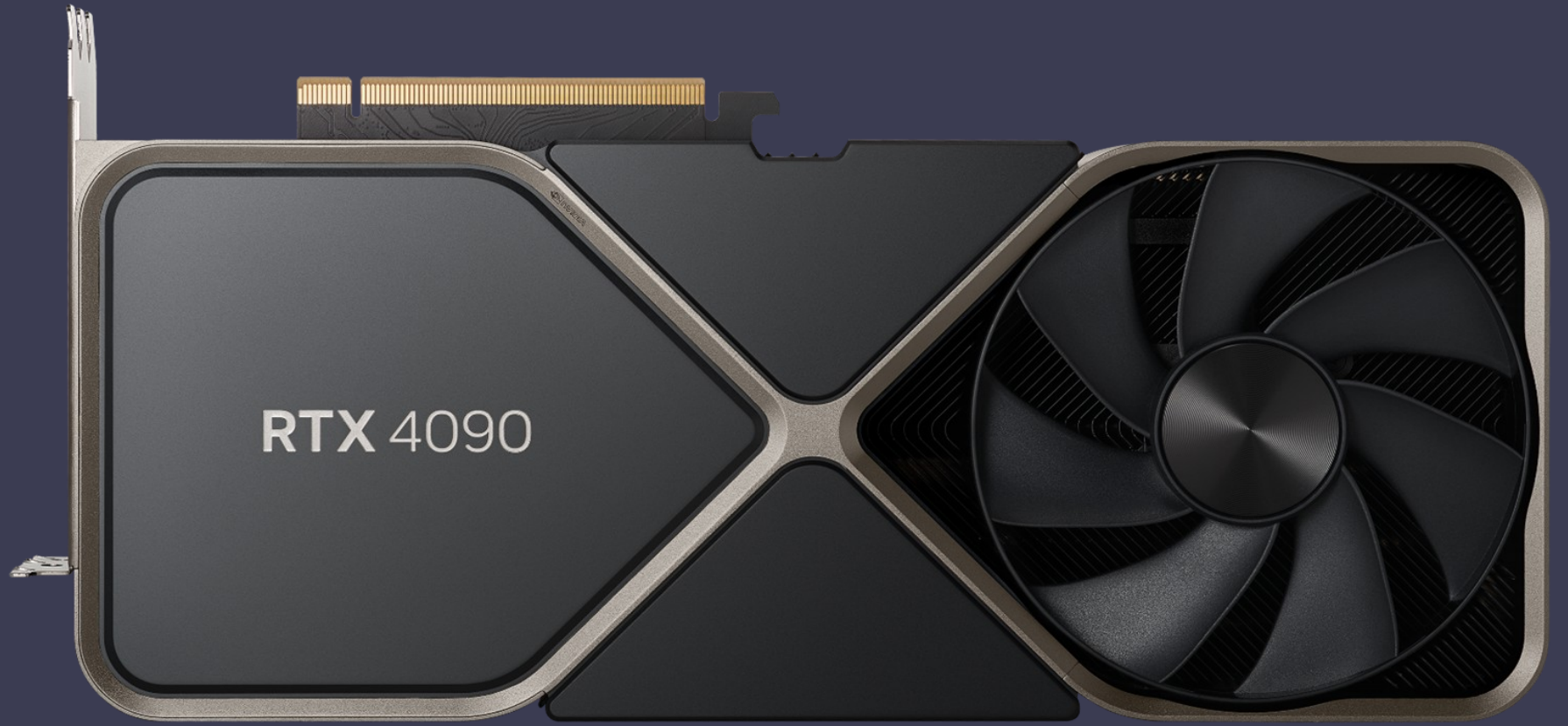
FPGA

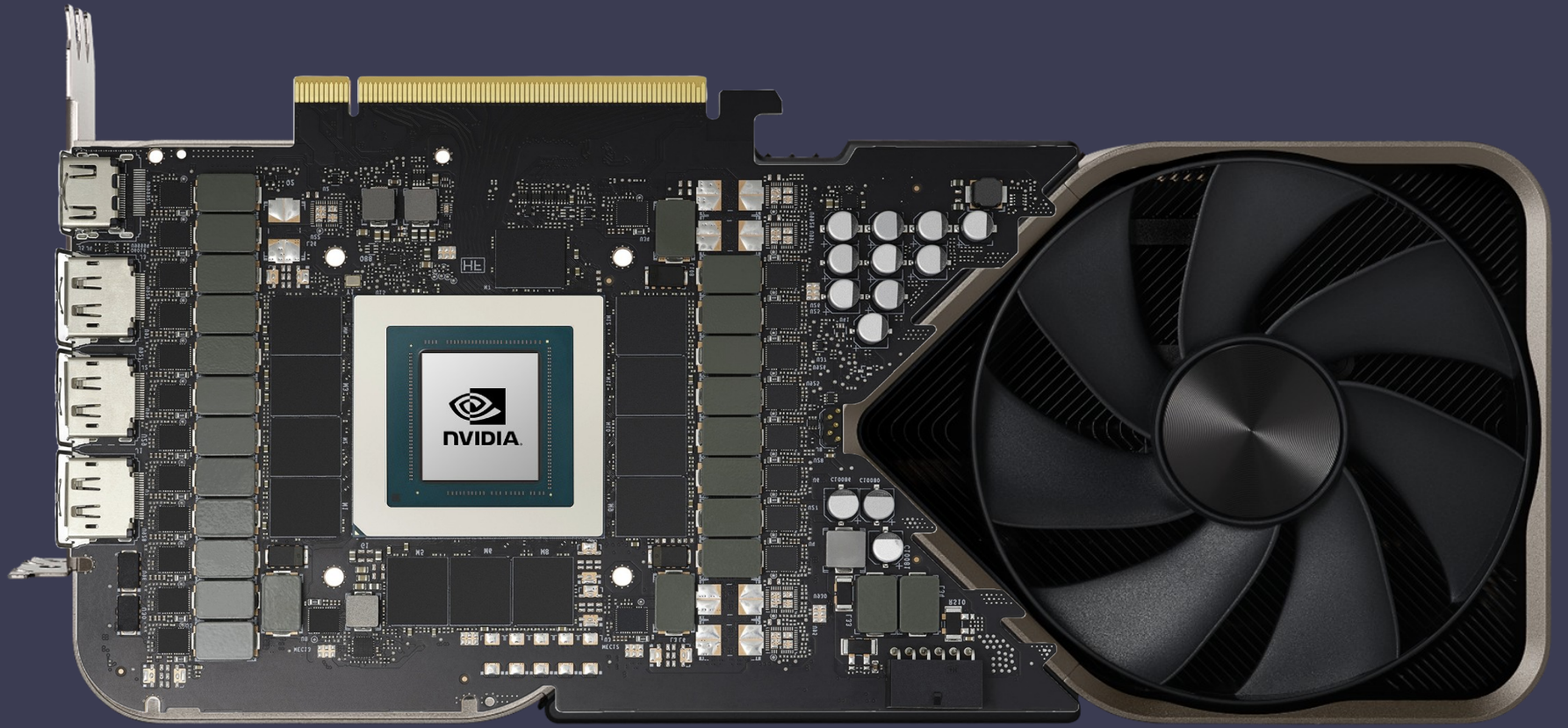
NVIDIA.
GEFORCE®
RTX

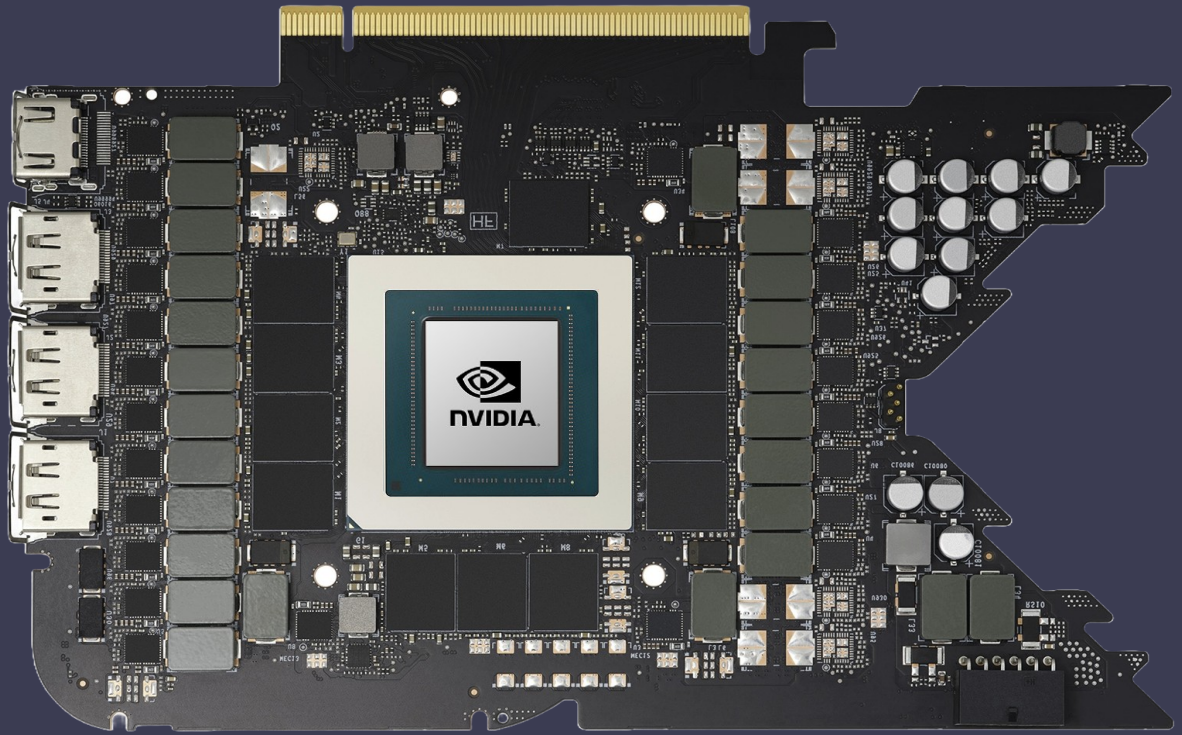

NVIDIA.
GEFORCE®
RTX

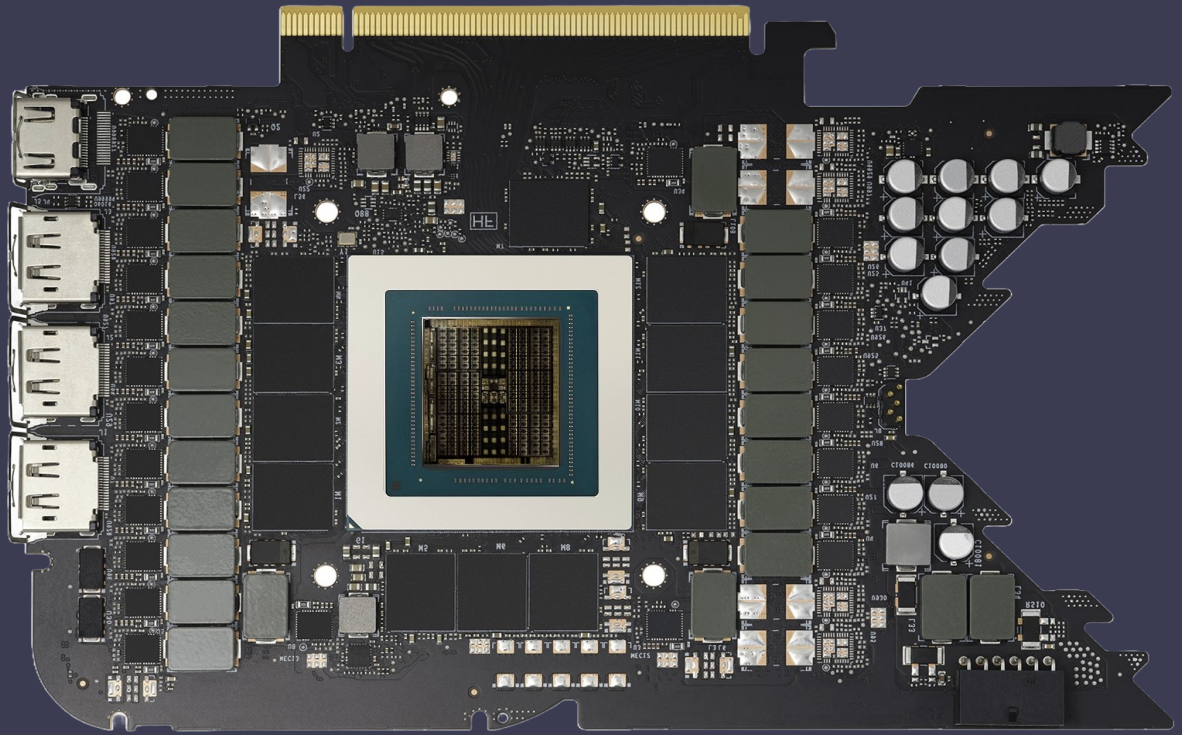

XII

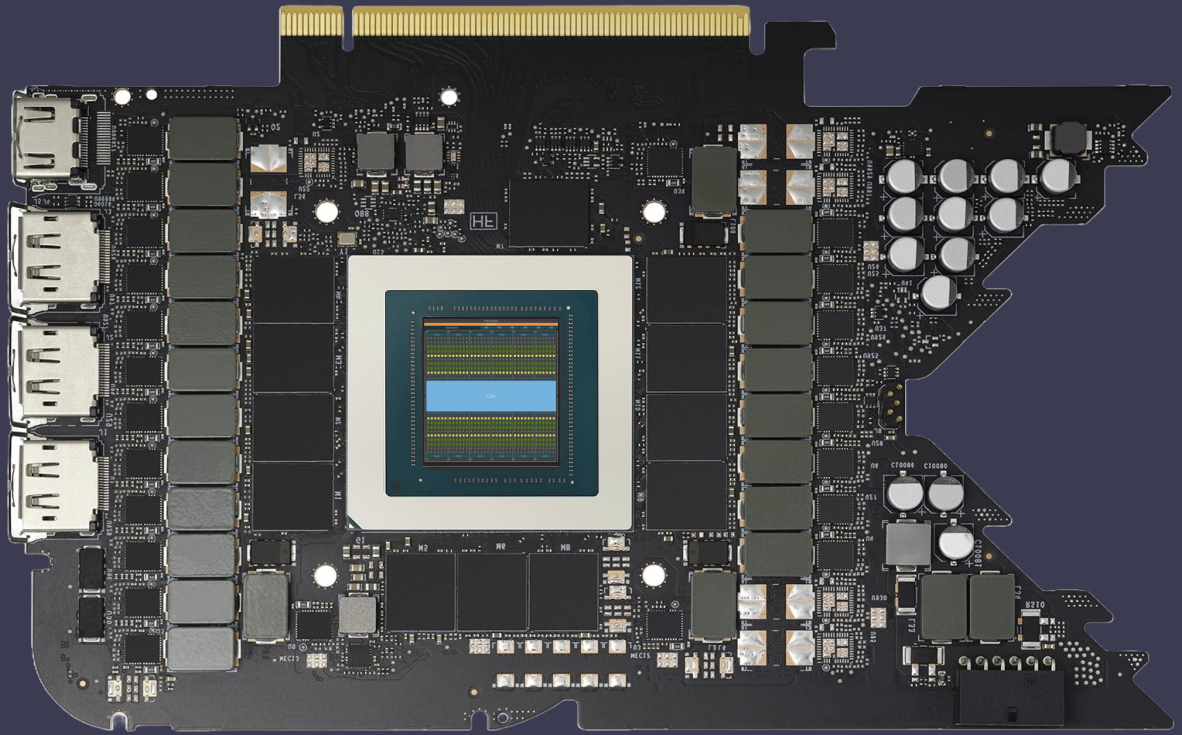
DXR

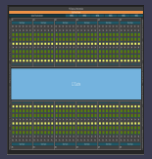

RTX 4090


NVIDIA


NVIDIA







PCI Express 4.0 Host Interface
GigaThread Engine
Optical Flow Accelerator
NVENC
NVENC
NVENC
NVDEC
NVDEC
NVDEC
Memory Controller
GPC
Raster Engine
TPC
SM
L2 Cache

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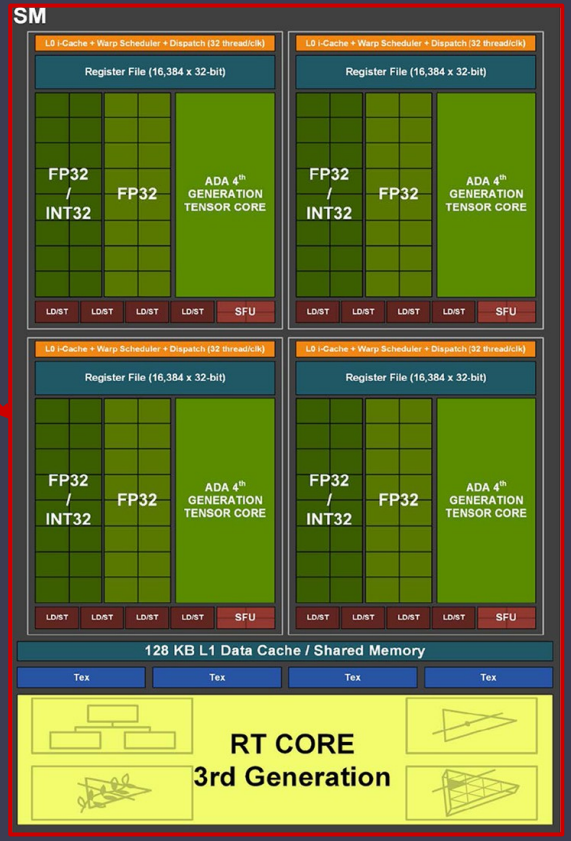
SM
L0 i-Cache + Warp Scheduler + Dispatch (32 thread/clk)
Register File (16,384 x 32-bit)
FP32 / INT32
FP32
ADA 4th GENERATION TENSOR CORE
LD/ST
SFU
128 KB L1 Data Cache / Shared Memory
Tex
RT CORE
3rd Generation

PCI Express 4.0 Host Interface
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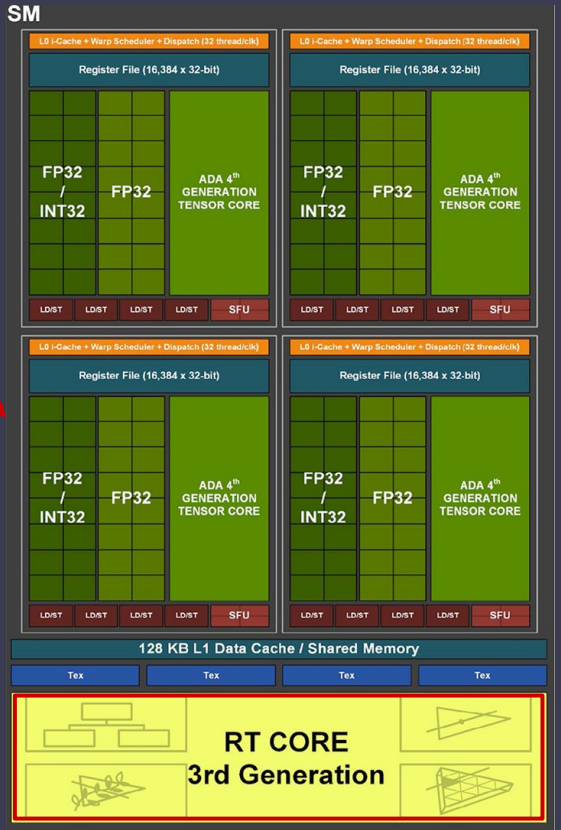
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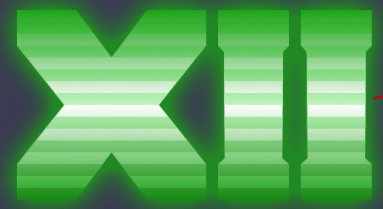
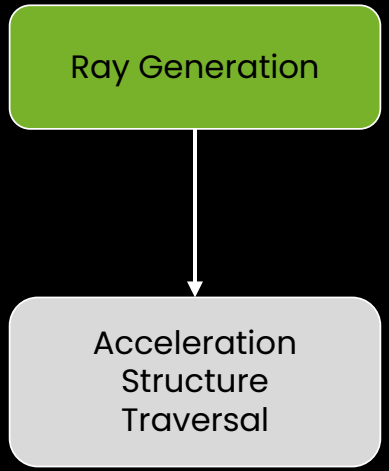
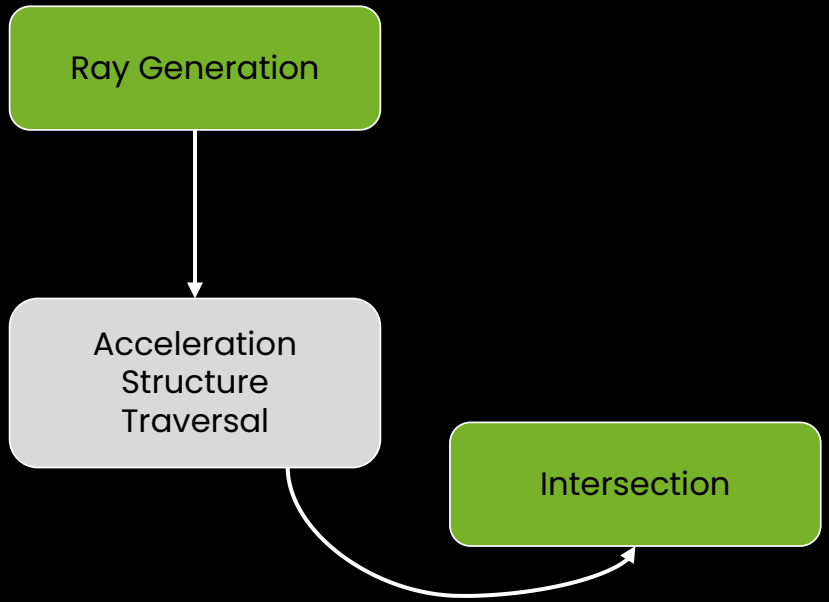
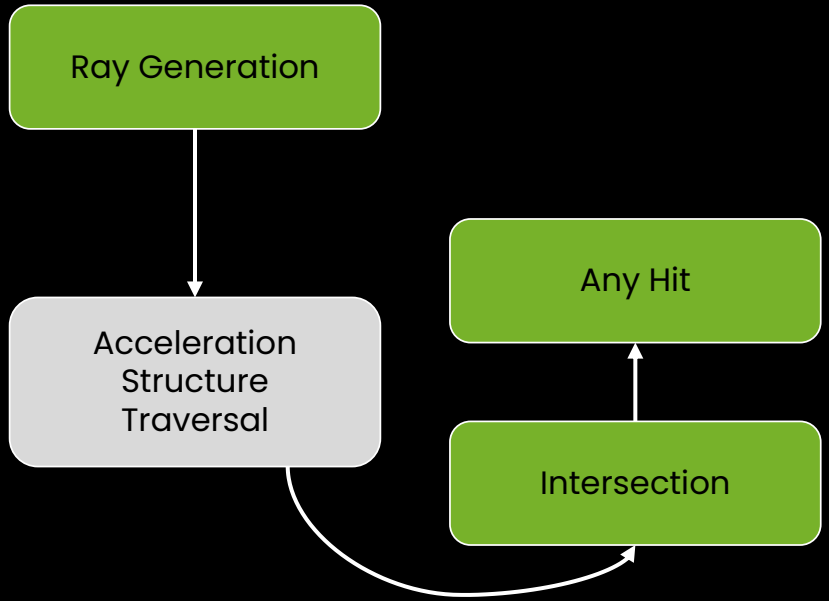

XII

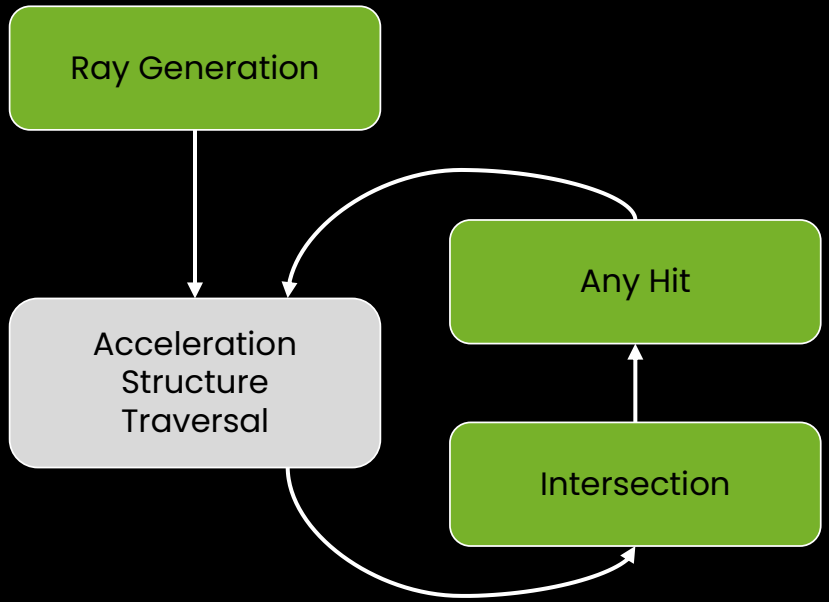
Ray Tracing pipeline

Ray Generation


Ray Generation
Acceleration
Structure
Traversal


Ray Generation
Acceleration Structure Traversal
Intersection


Ray Generation
Acceleration Structure Traversal
Any Hit
Intersection


Ray Generation
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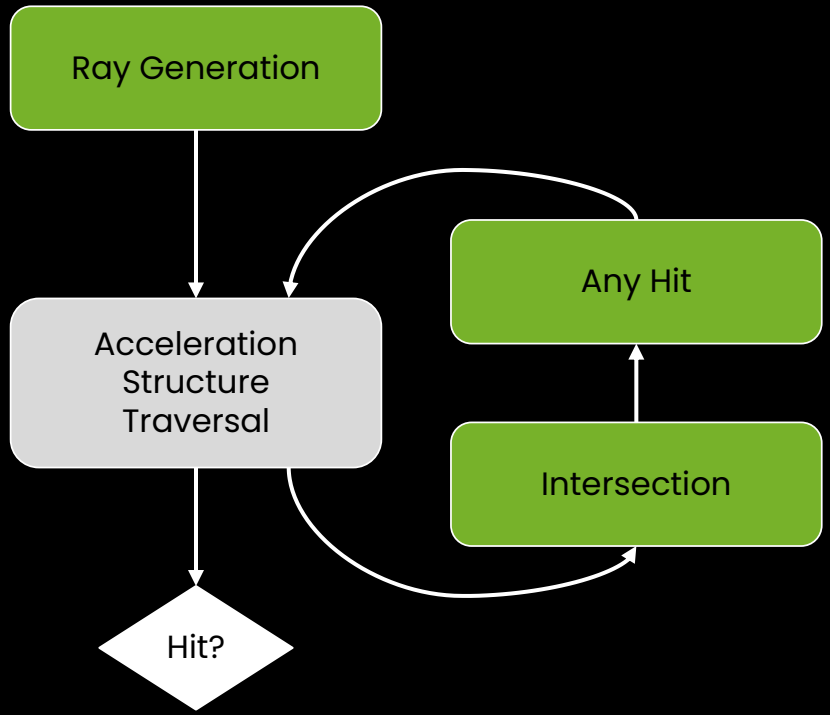
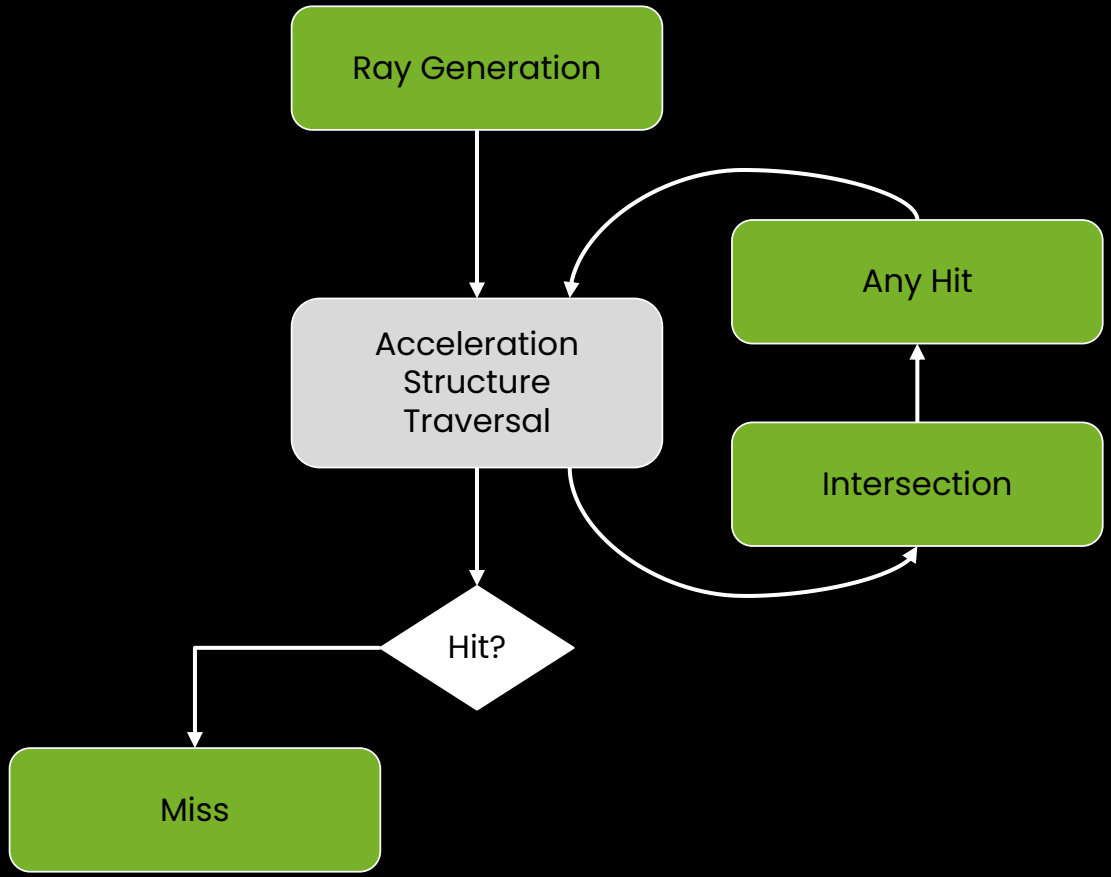
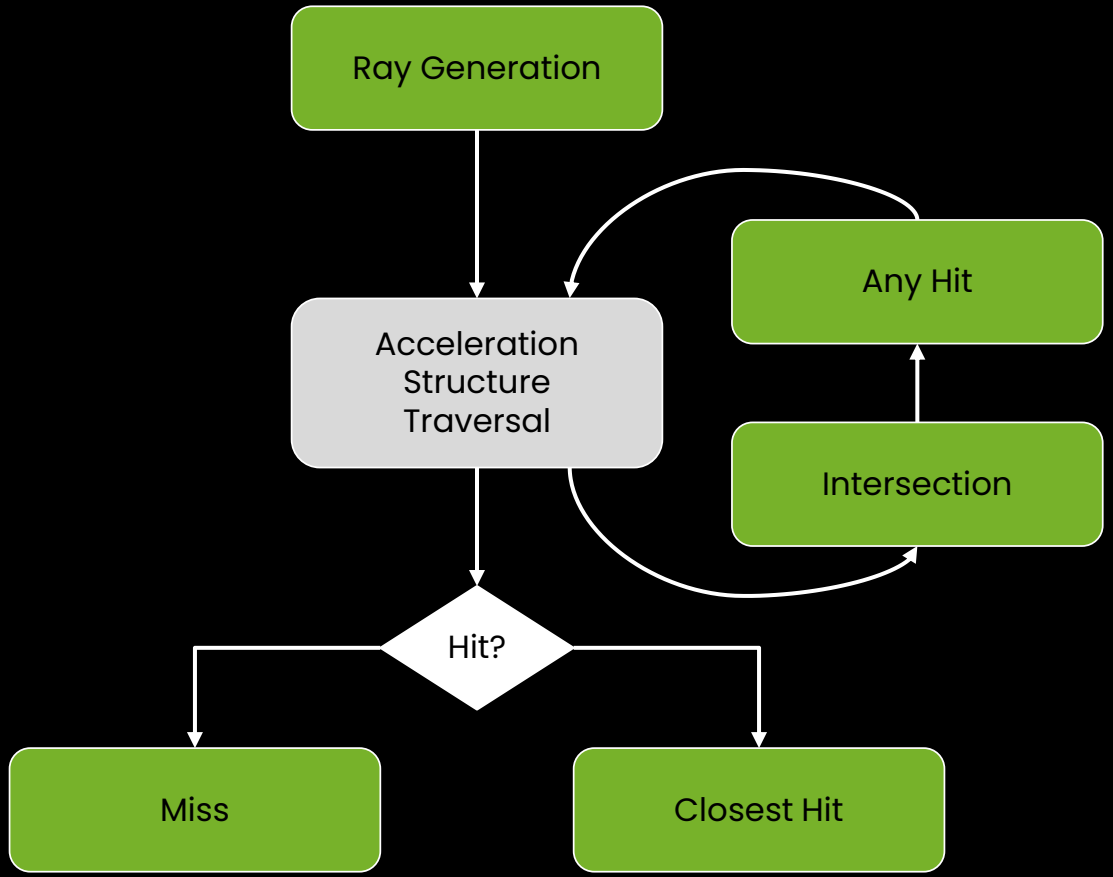
Intersection


Ray Generation
Acceleration Structure Traversal
Any Hit
Intersection
Hit?


Ray Generation
Acceleration Structure Traversal
Any Hit
Intersection
Hit?
Miss


Ray Generation
Acceleration Structure Traversal
Any Hit
Intersection
Hit?
Miss
Closest Hit

Ray Generation

Acceleration Structure Traversal

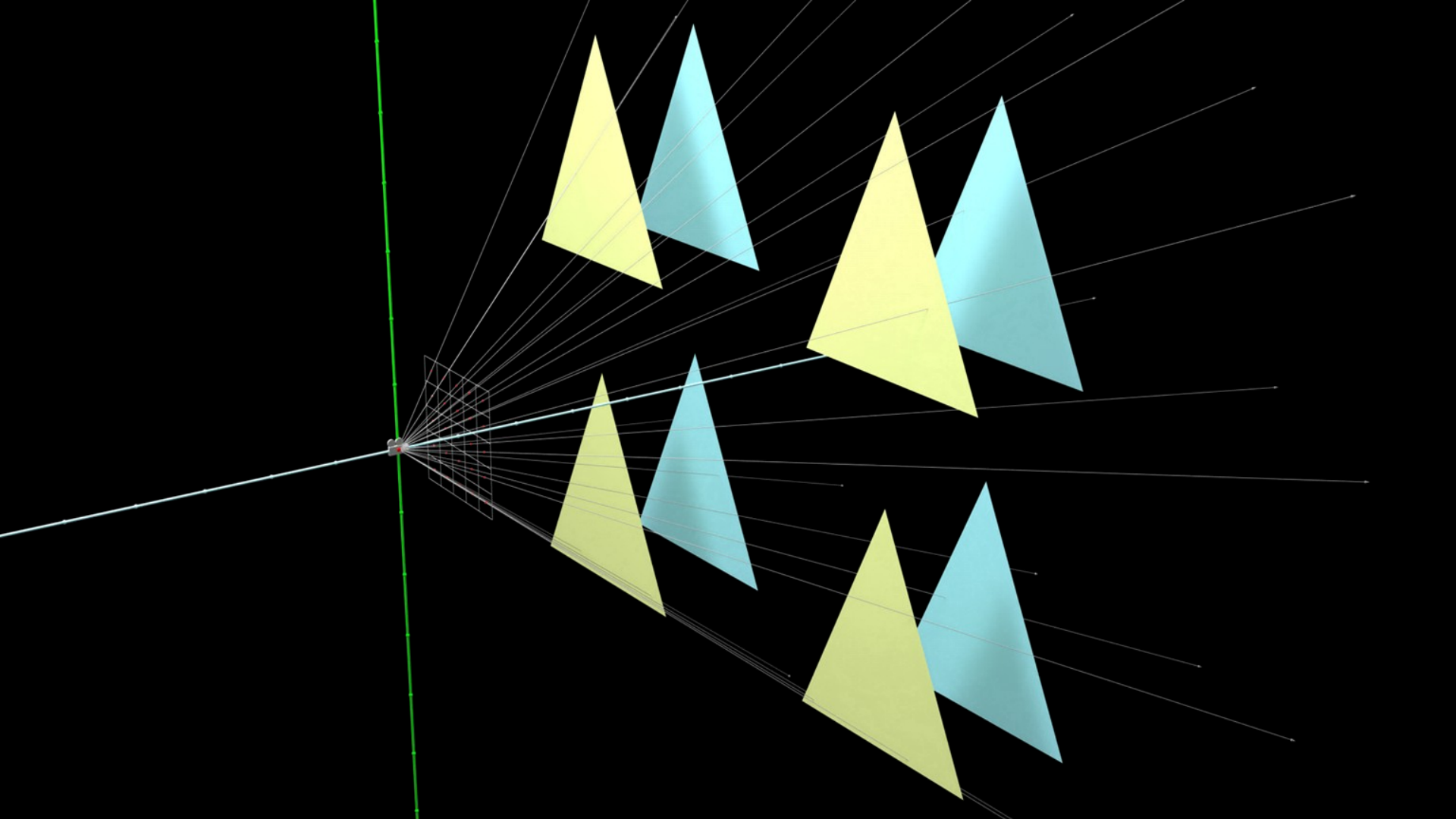
Any Hit

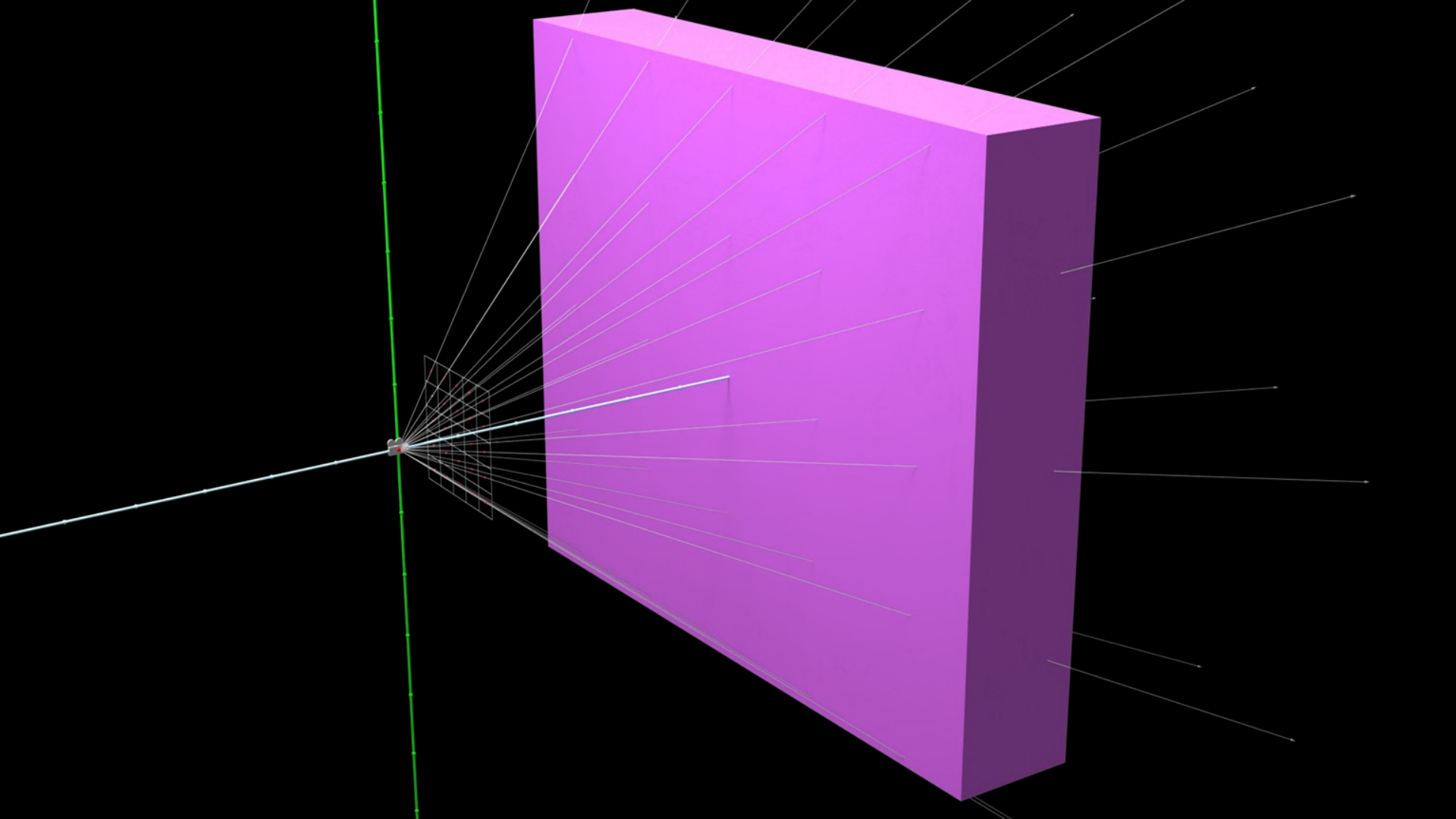
Intersection

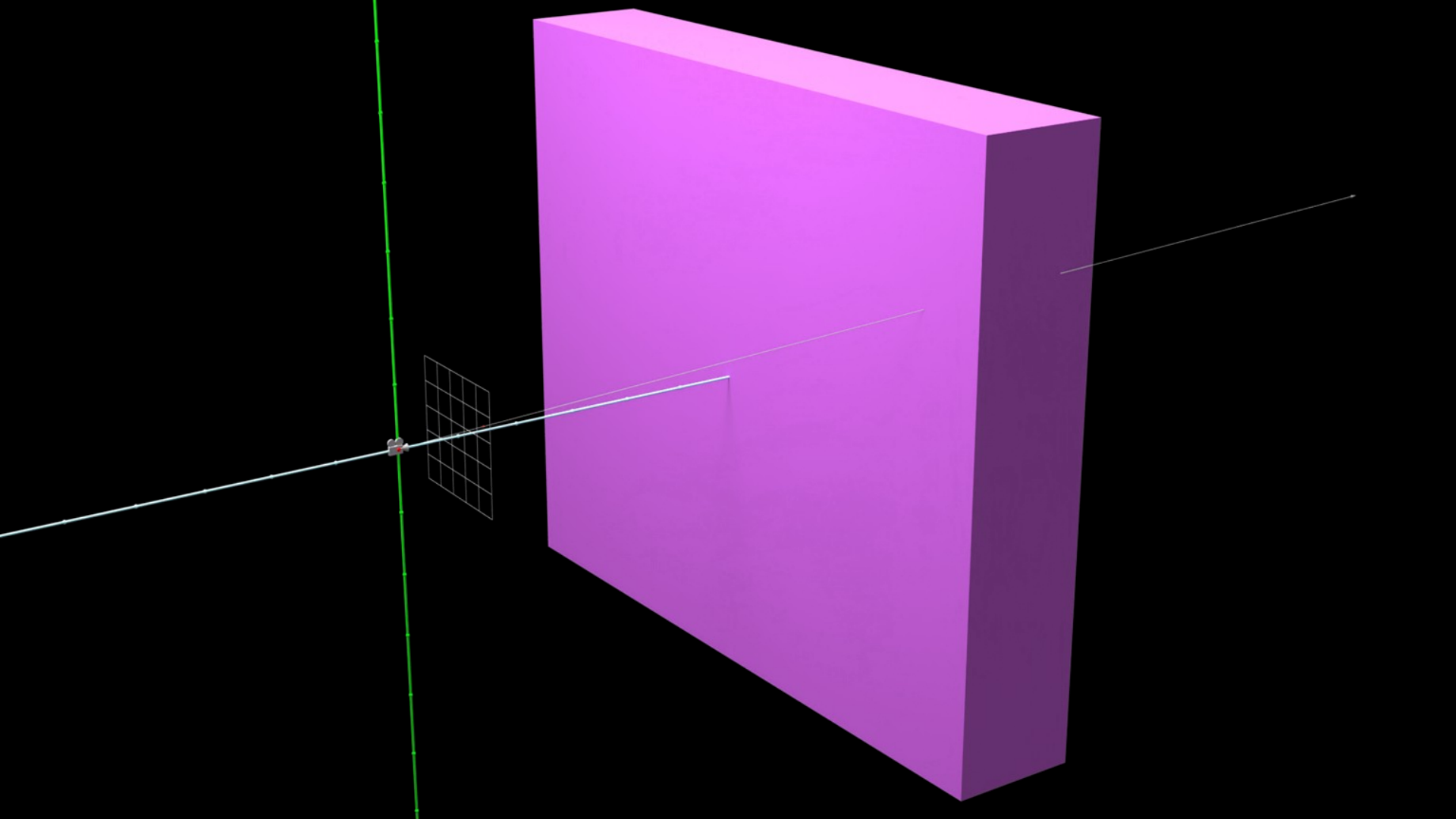
Hit?

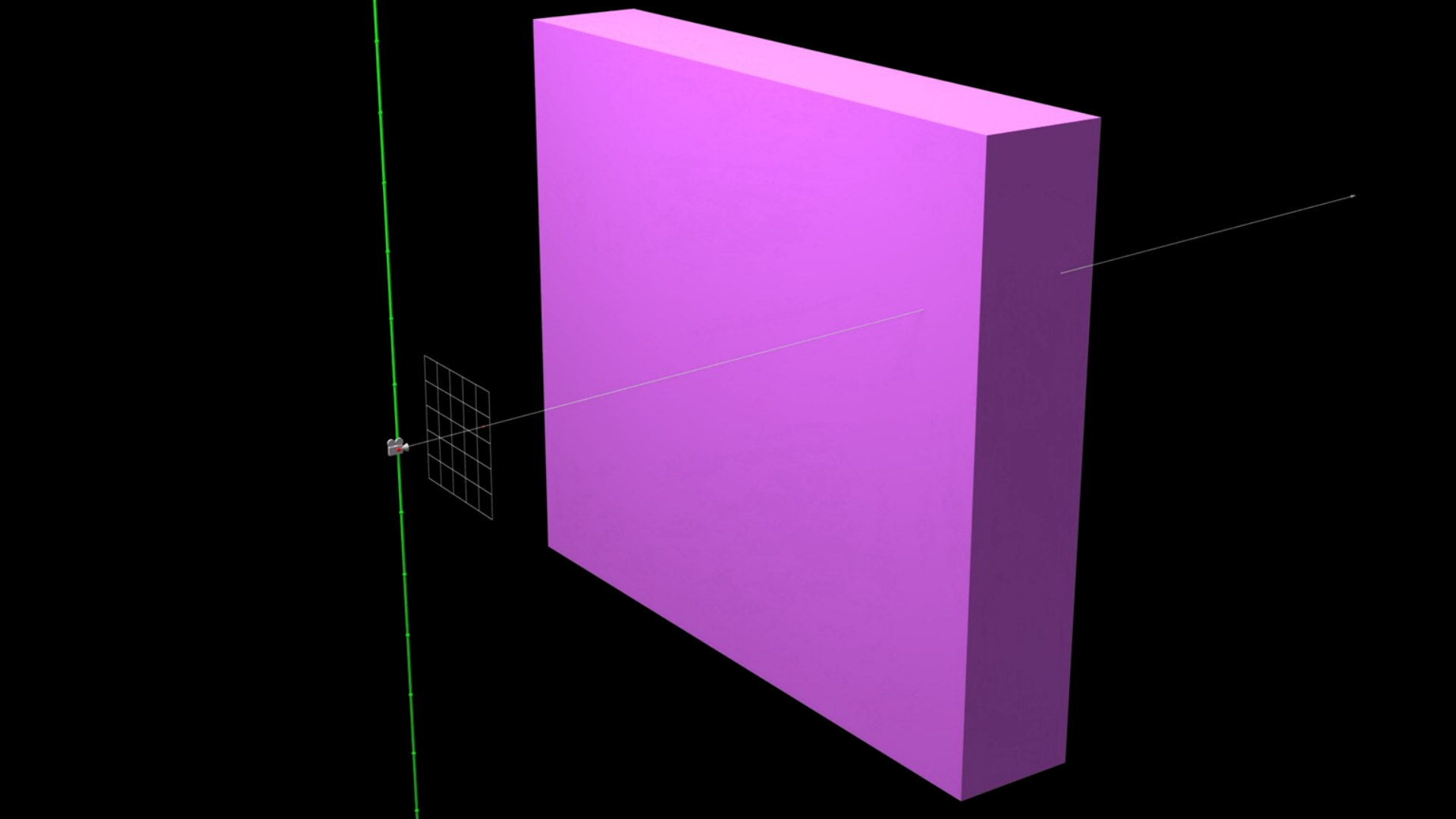
Miss

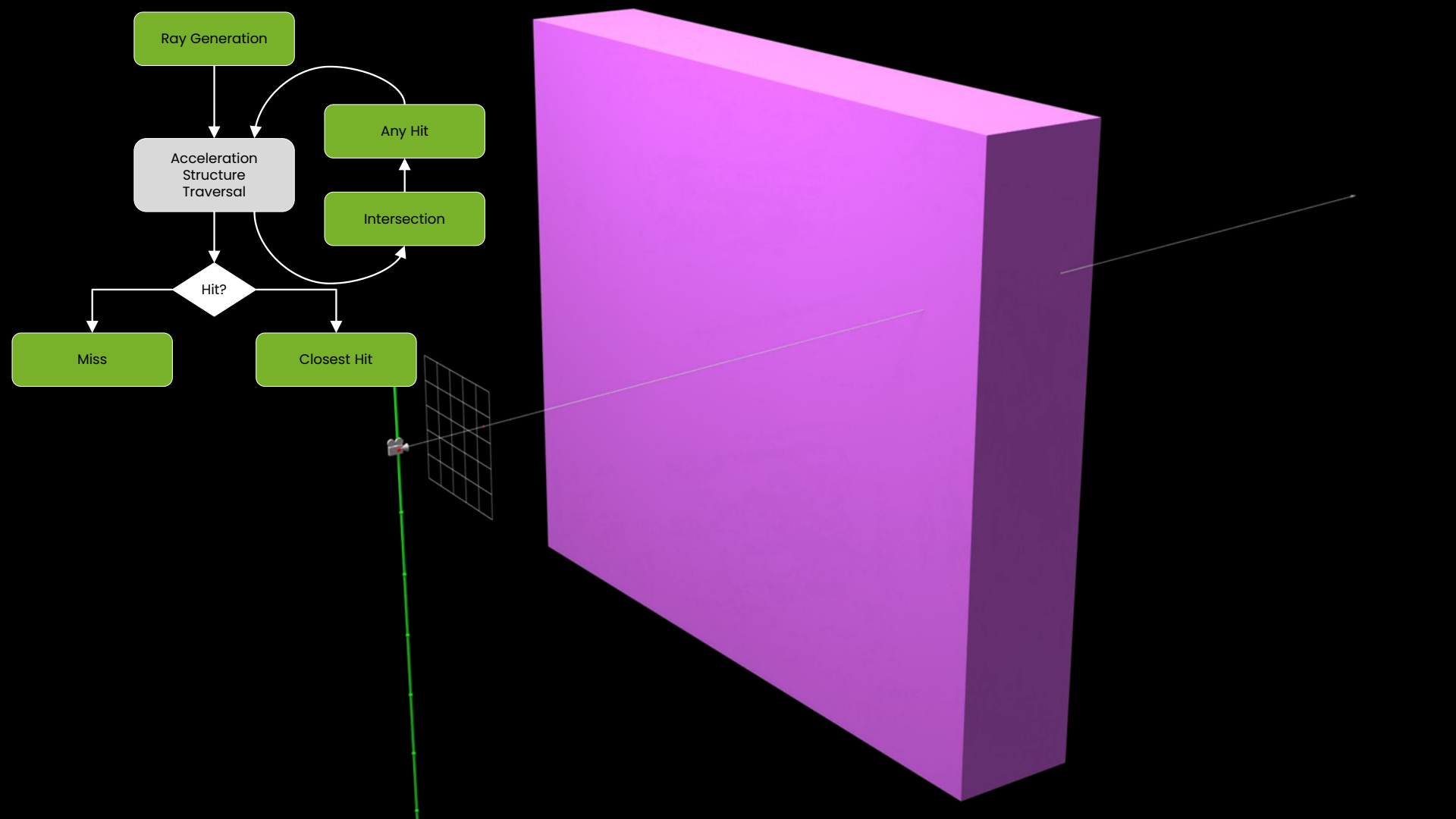
Closest Hit










Ray Generation
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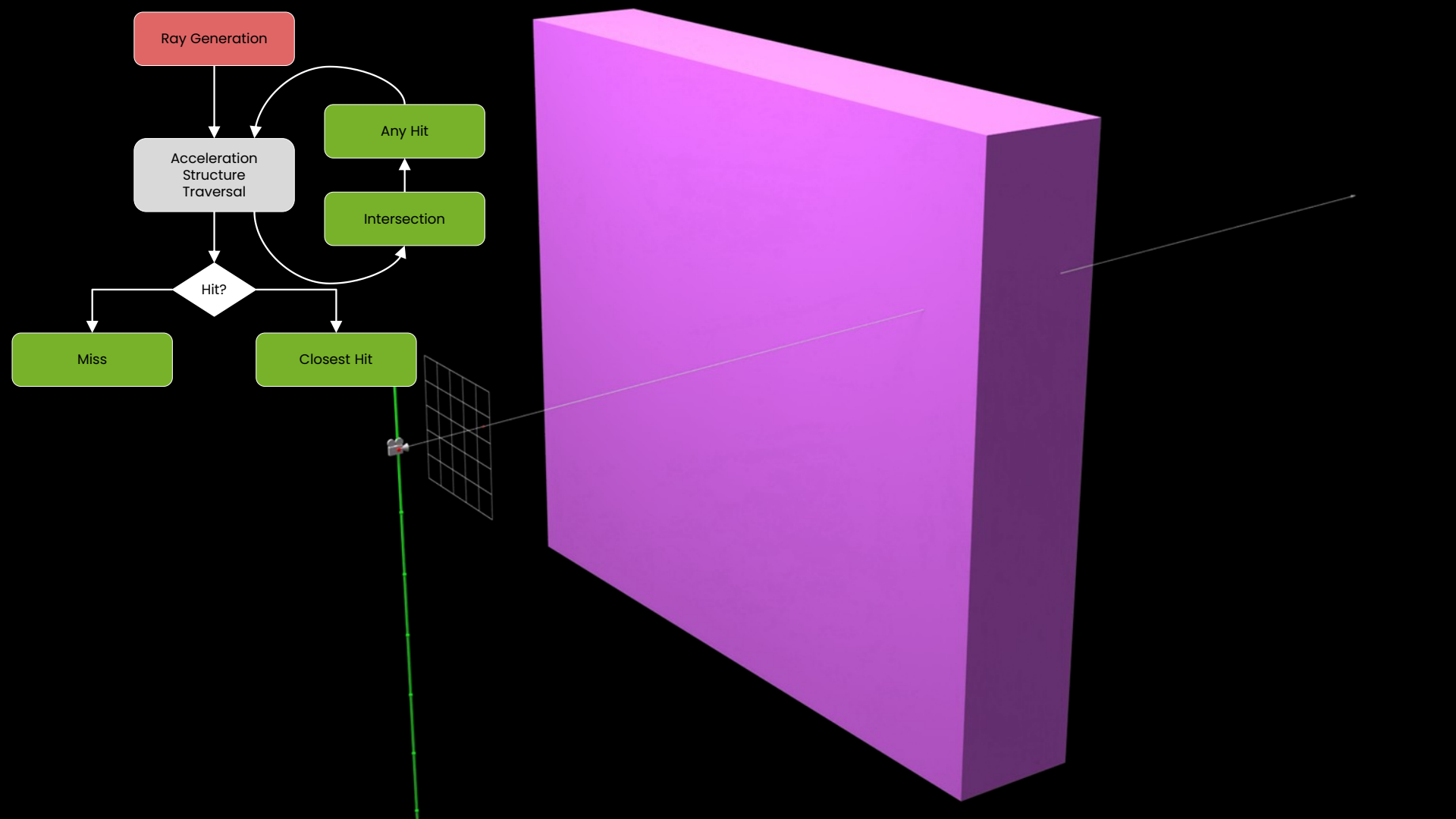
Any Hit
Intersection
Hit?
Miss
Closest Hit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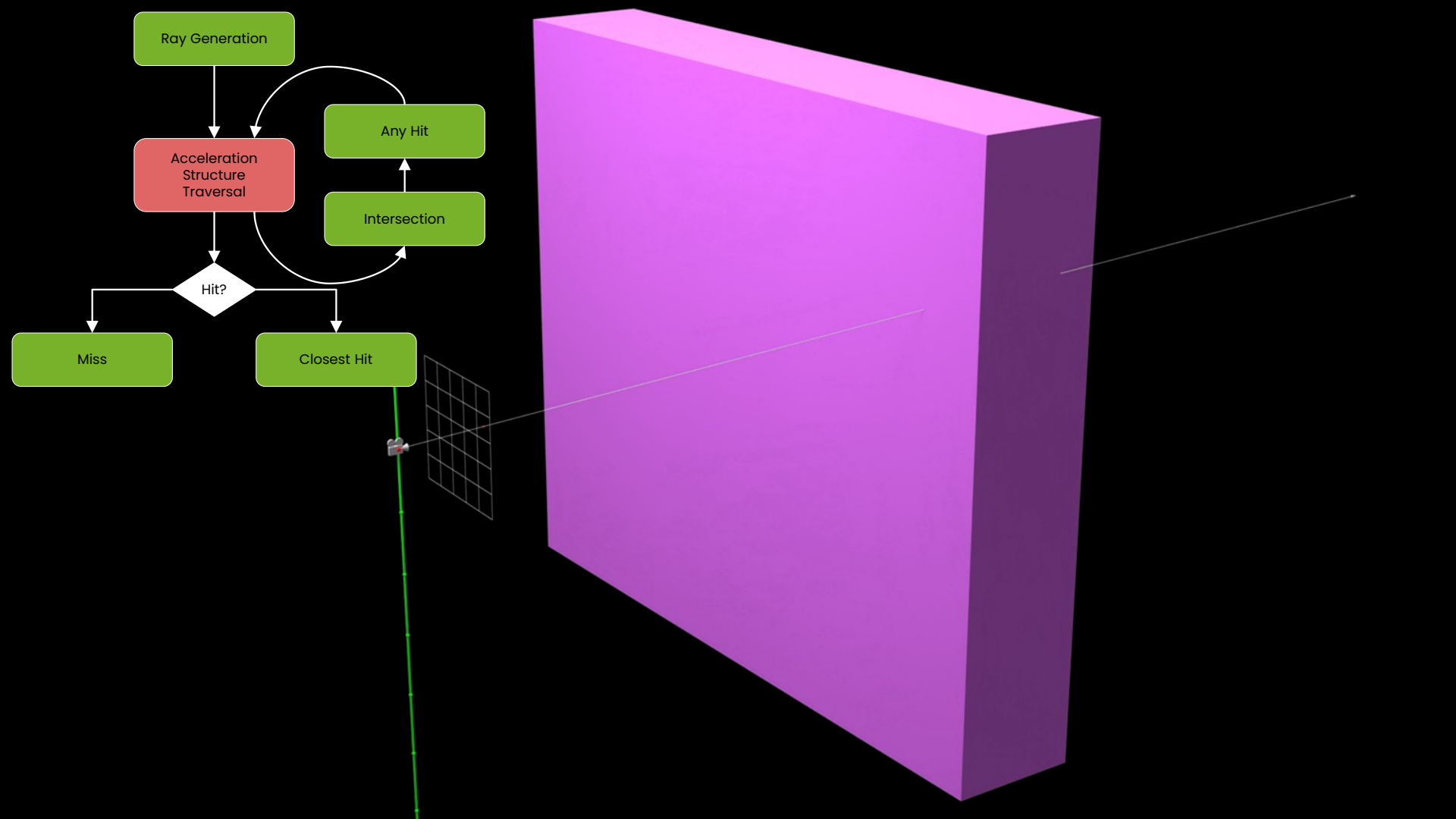
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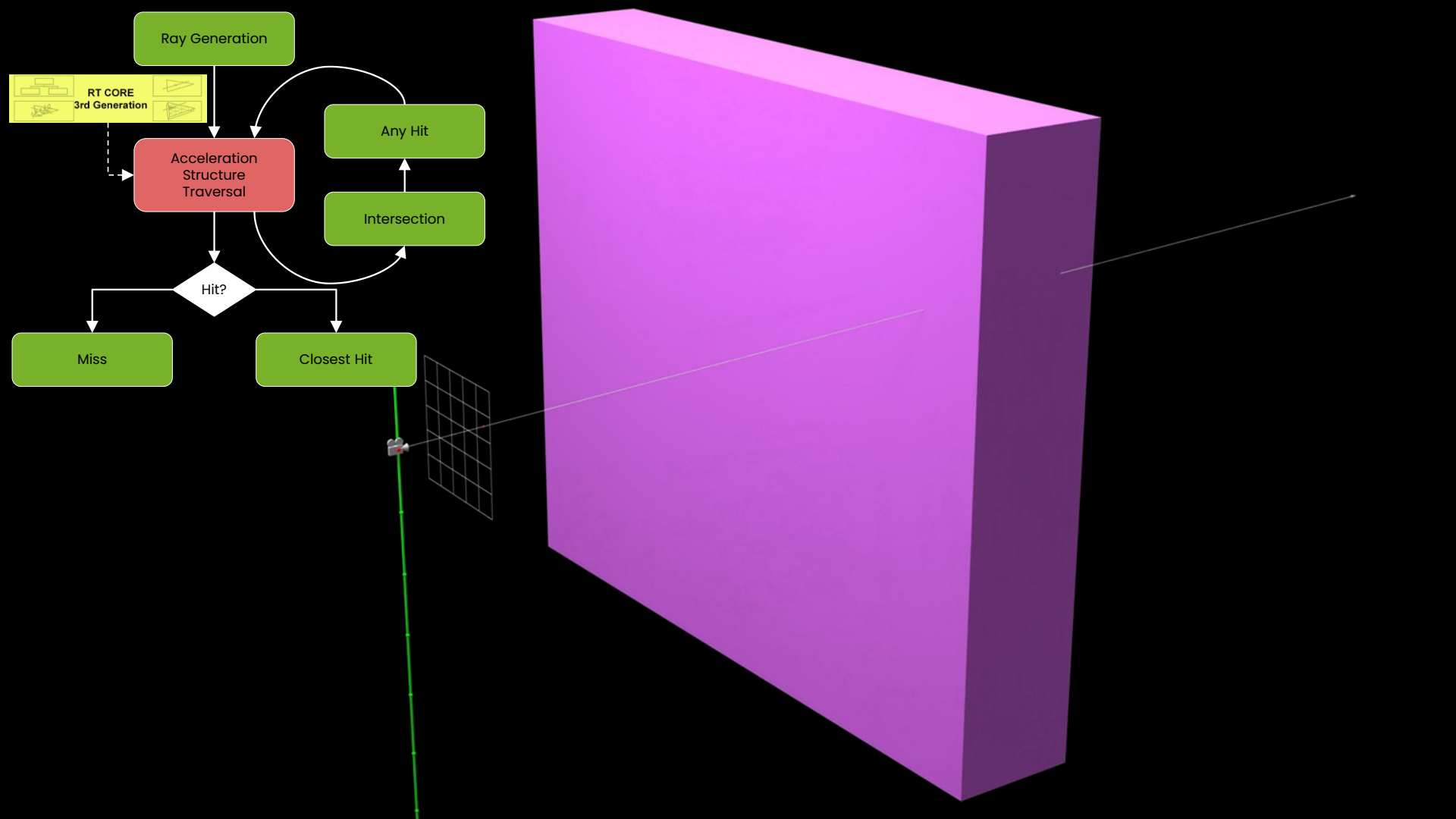
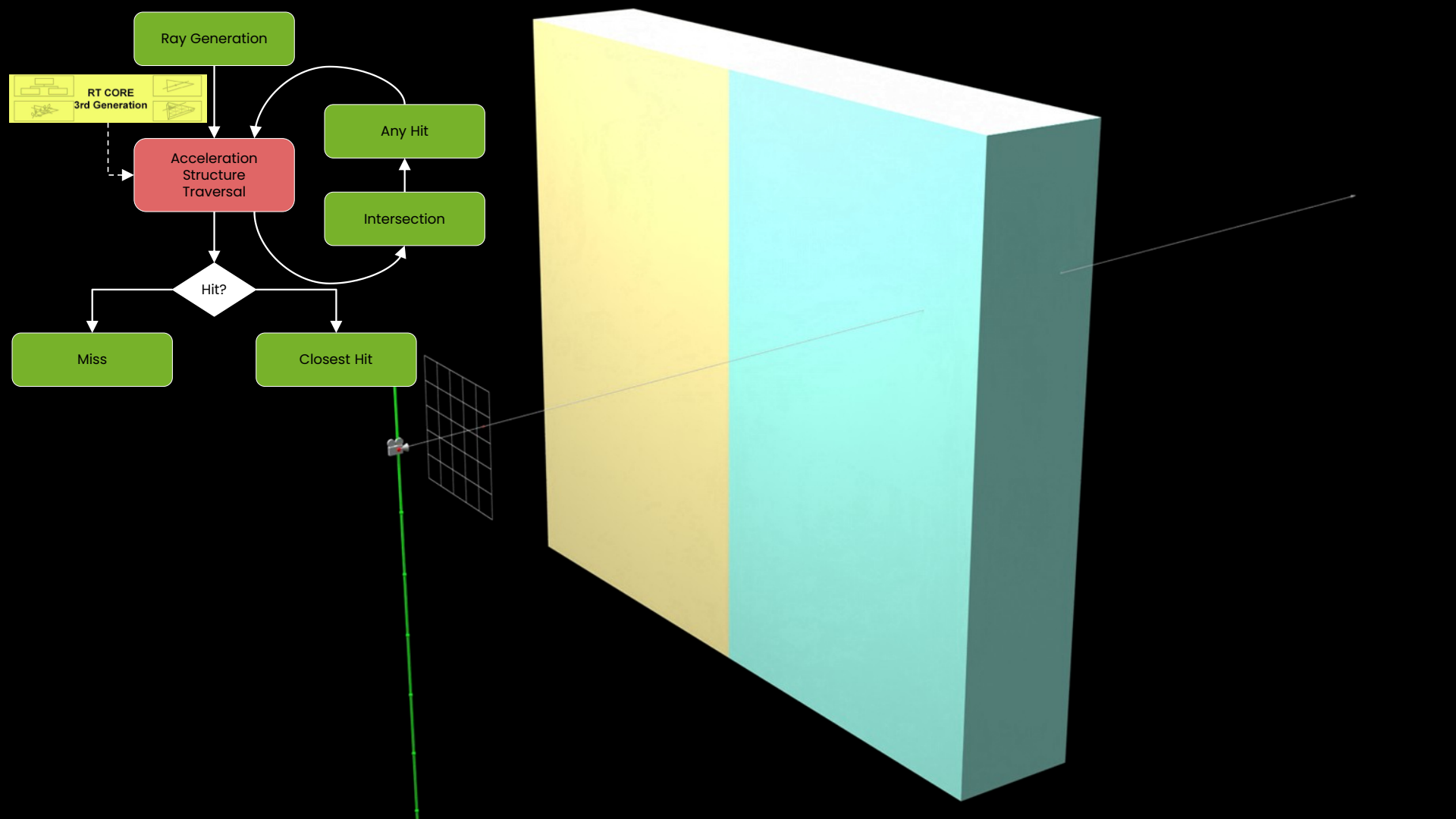
Intersection
Hit?
Miss
Closest Hit


Ray Generation
RT CORE
3rd Generation
Acceleration
Structure
Traversal
Any Hit
Intersection
Hit?
Miss
Closest Hit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RT CORE
3rd Generation
Acceleration
Structure
Traversal
Any Hit
Intersection
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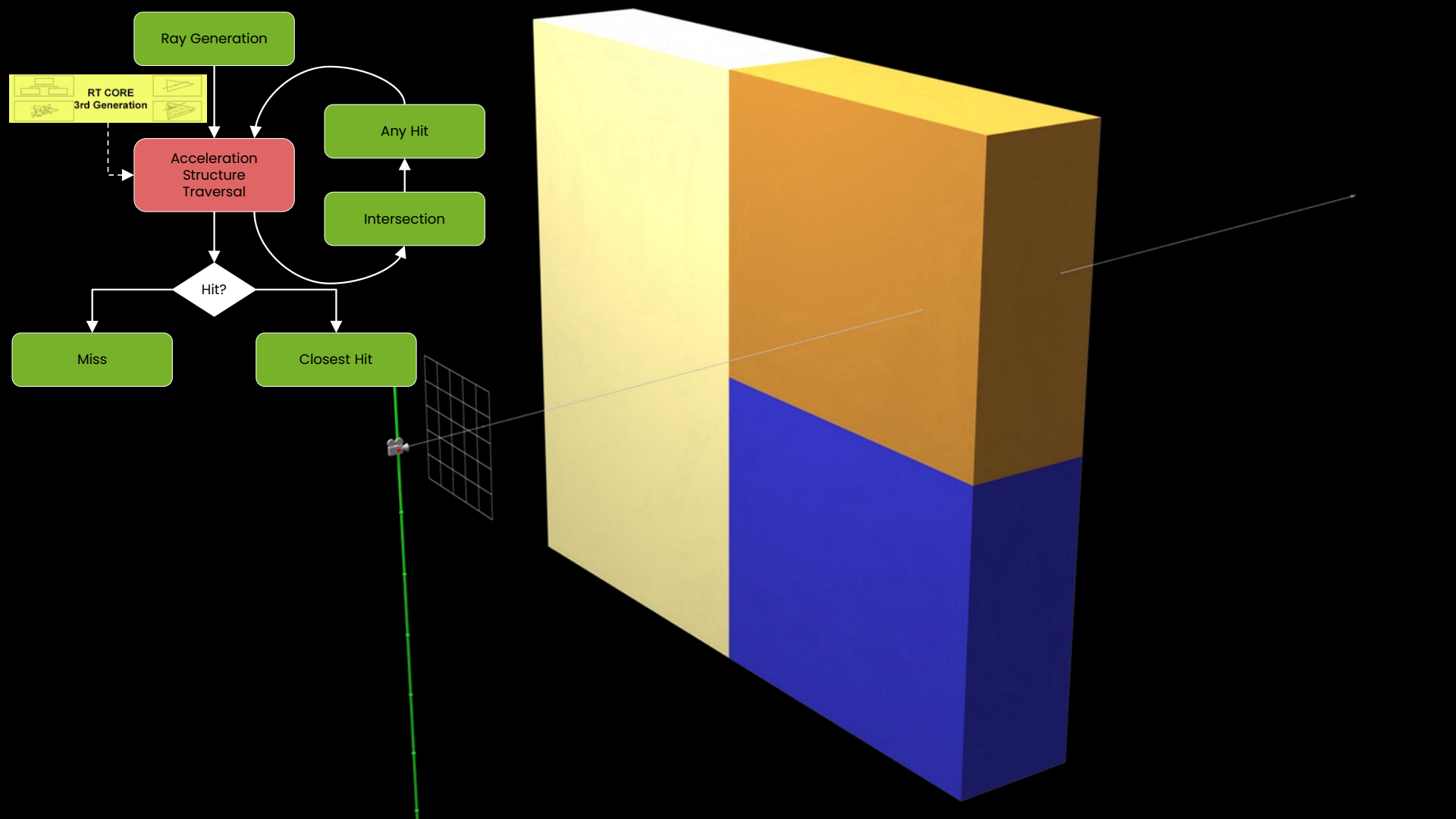
Miss
Closest Hit


Ray Generation
RT CORE
3rd Generation
Any Hit
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Miss
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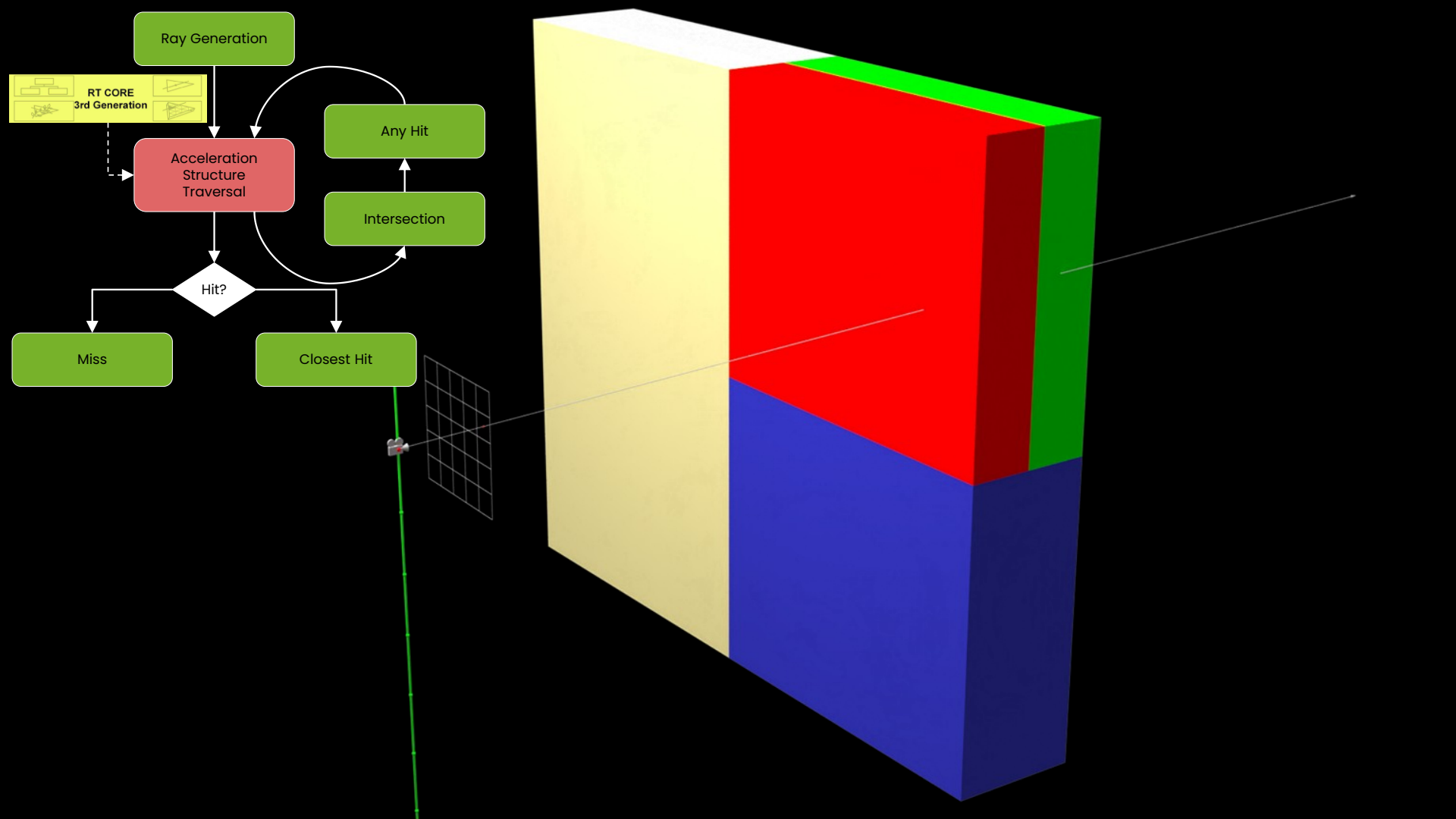
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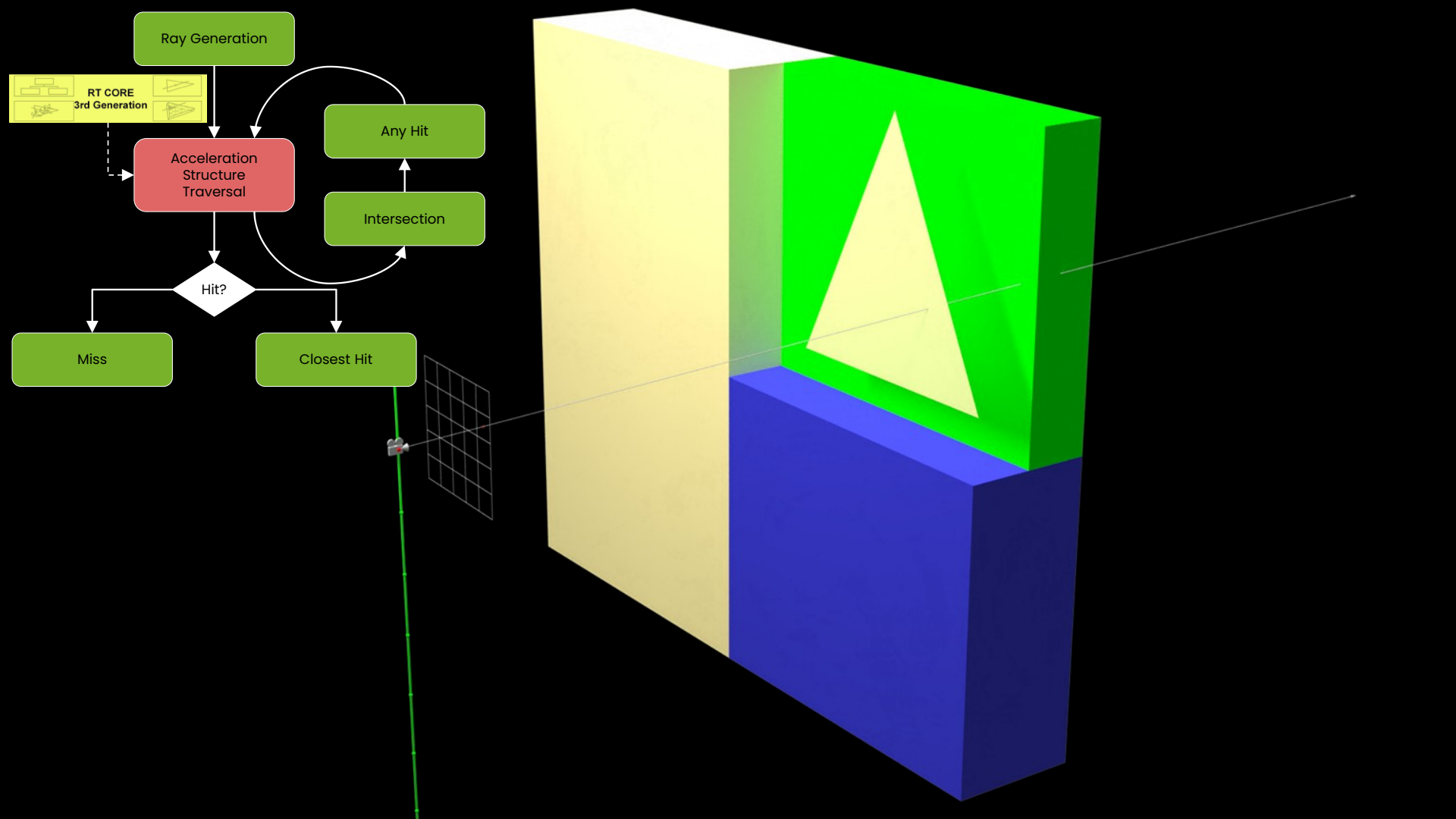
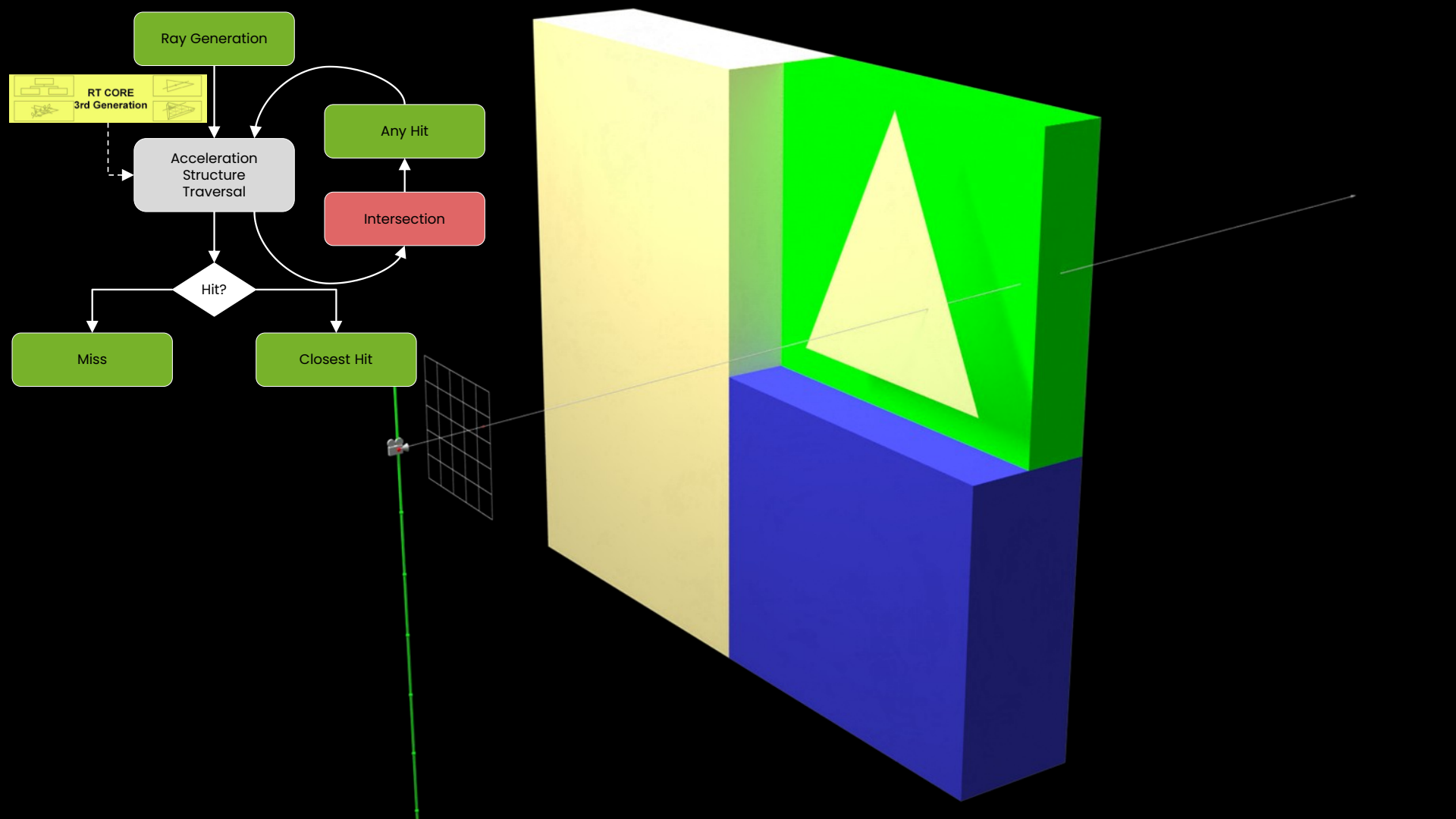
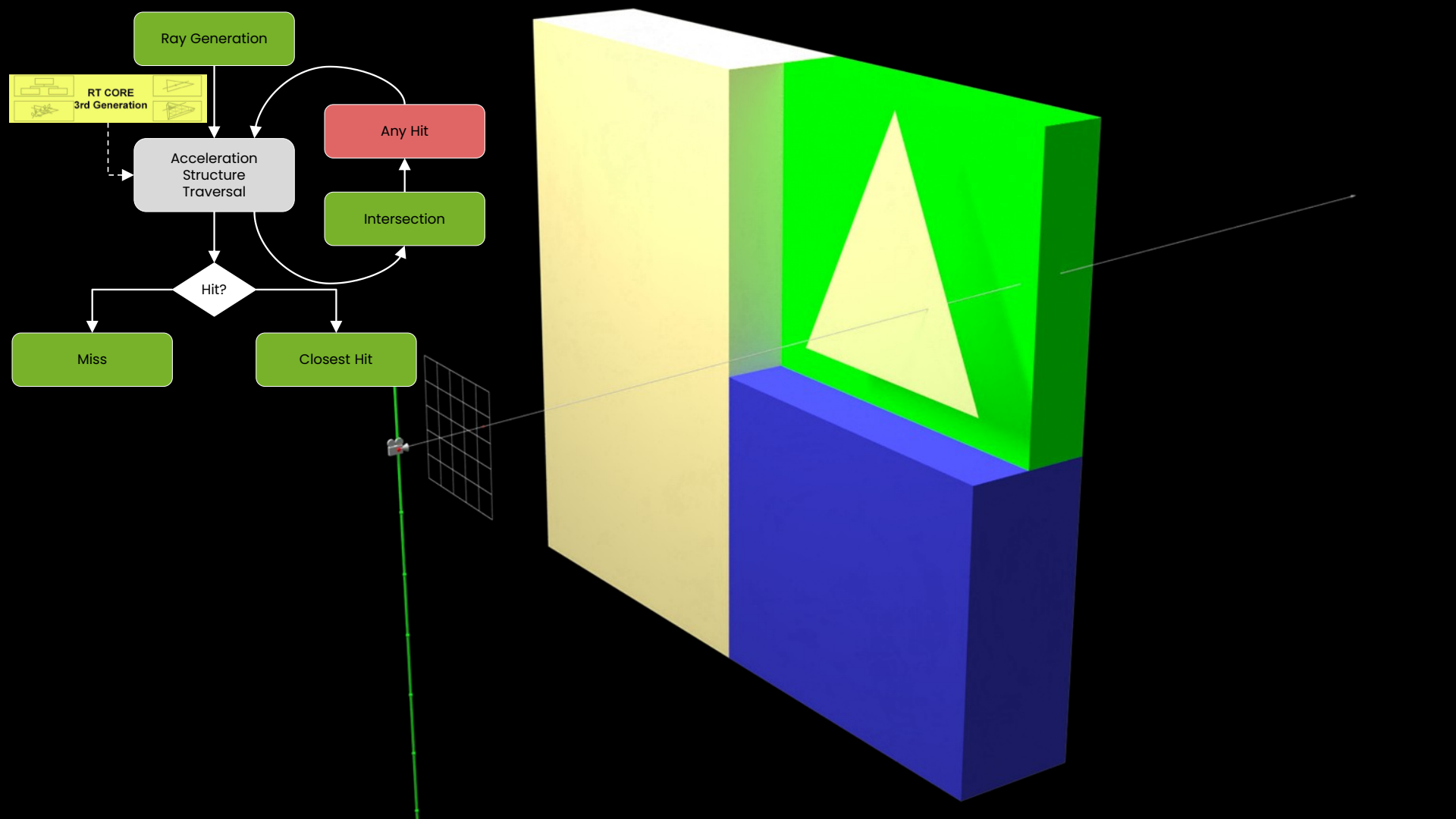
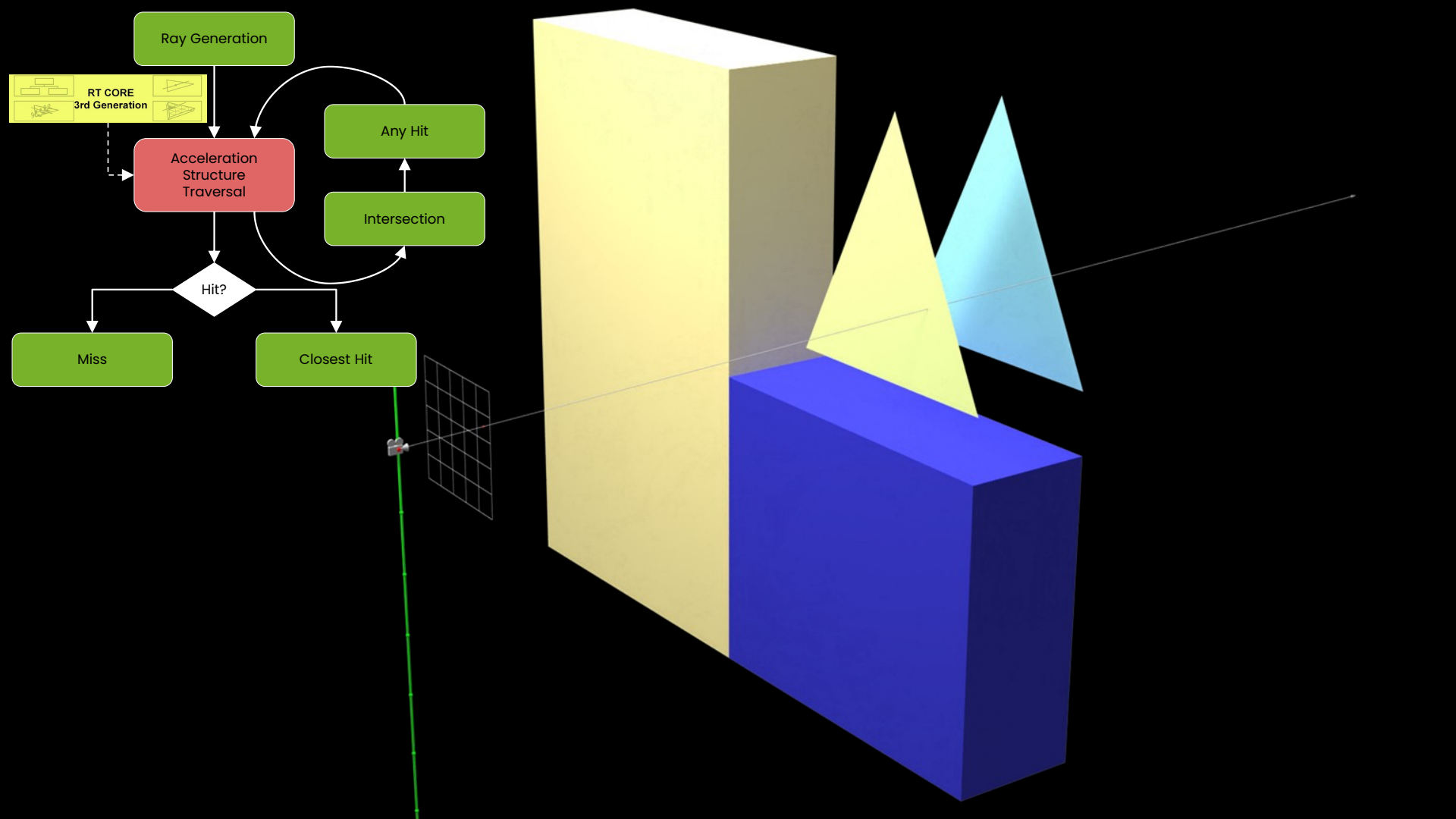
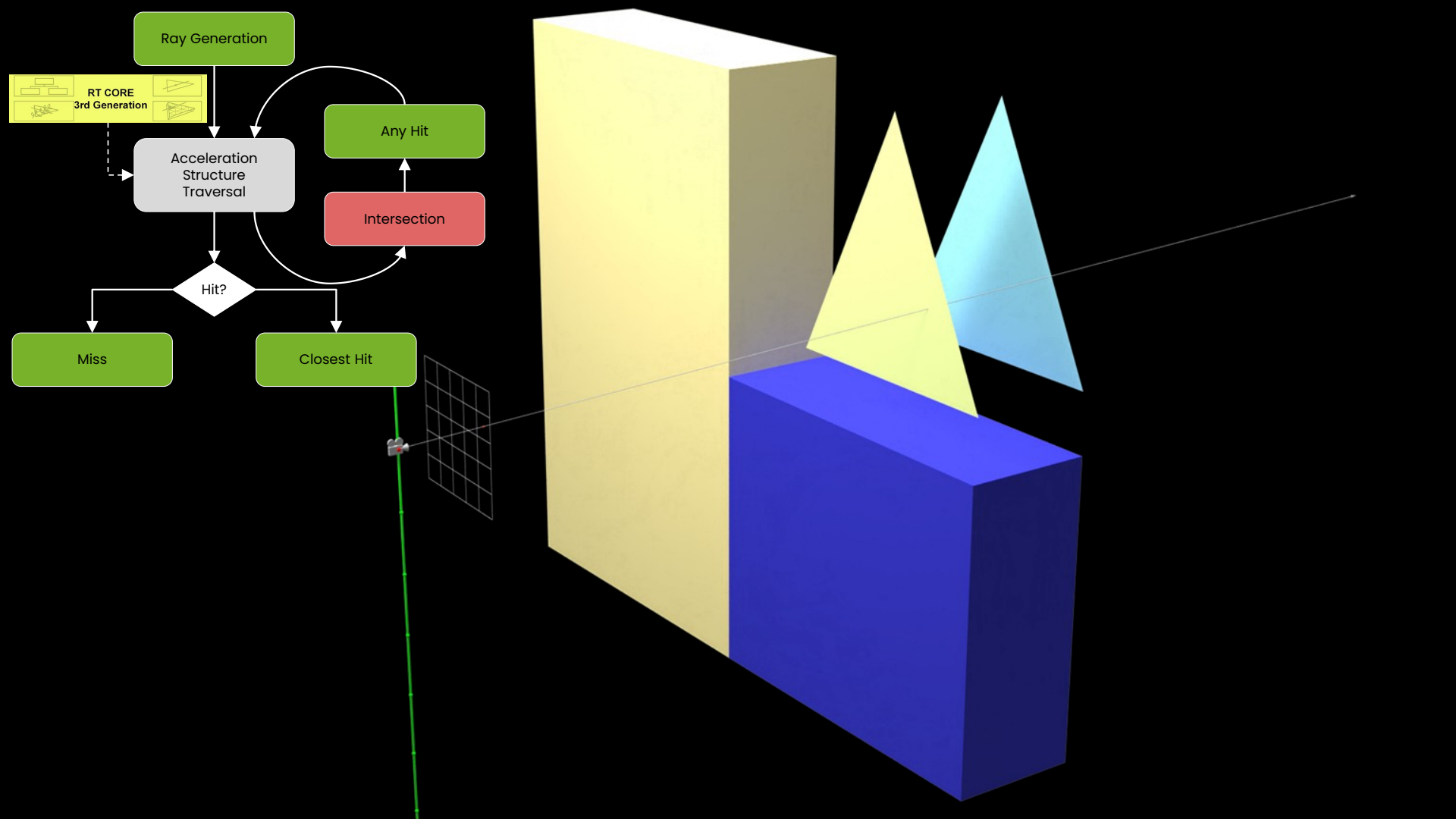
Miss
Closest Hit

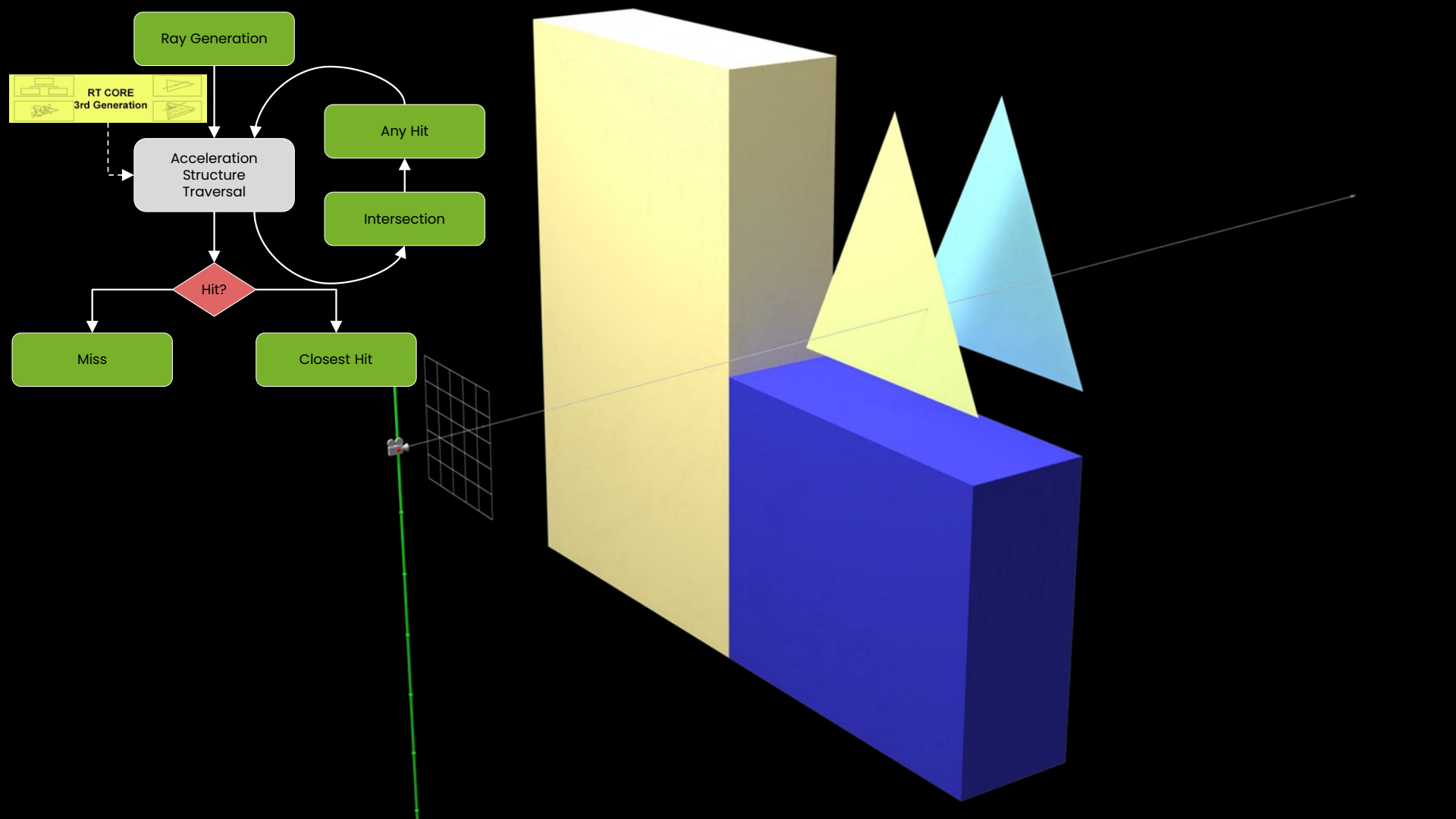

Ray Generation
RT CORE
3rd Generation
Acceleration
Structure
Traversal
Any Hit
Intersection
Hit?
Miss
Closest Hit

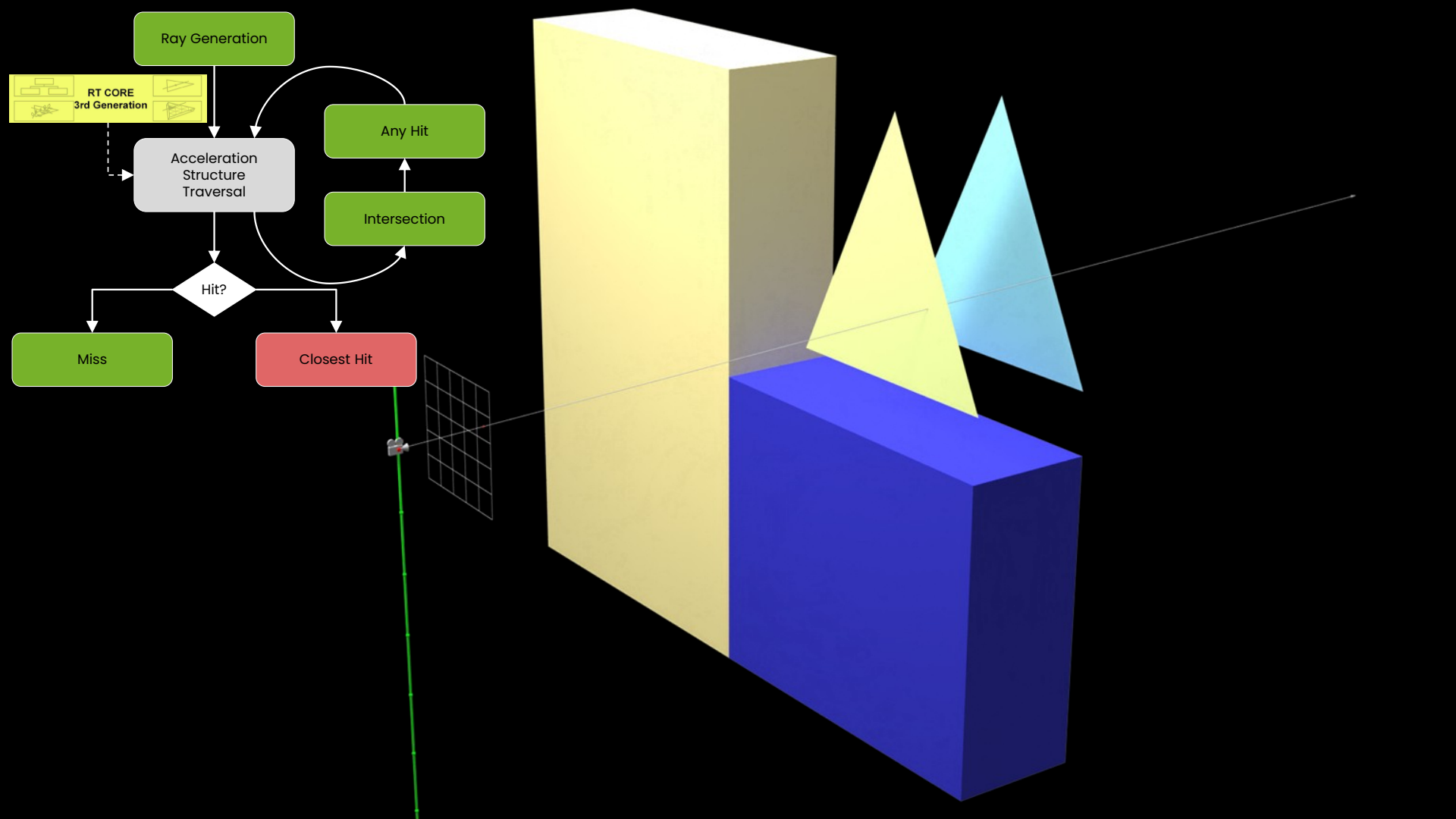

Ray Generation
RT CORE
3rd Generation
Any Hit
Acceleration
Structure
Traversal
Intersection
Hit?
Miss
Closest Hit

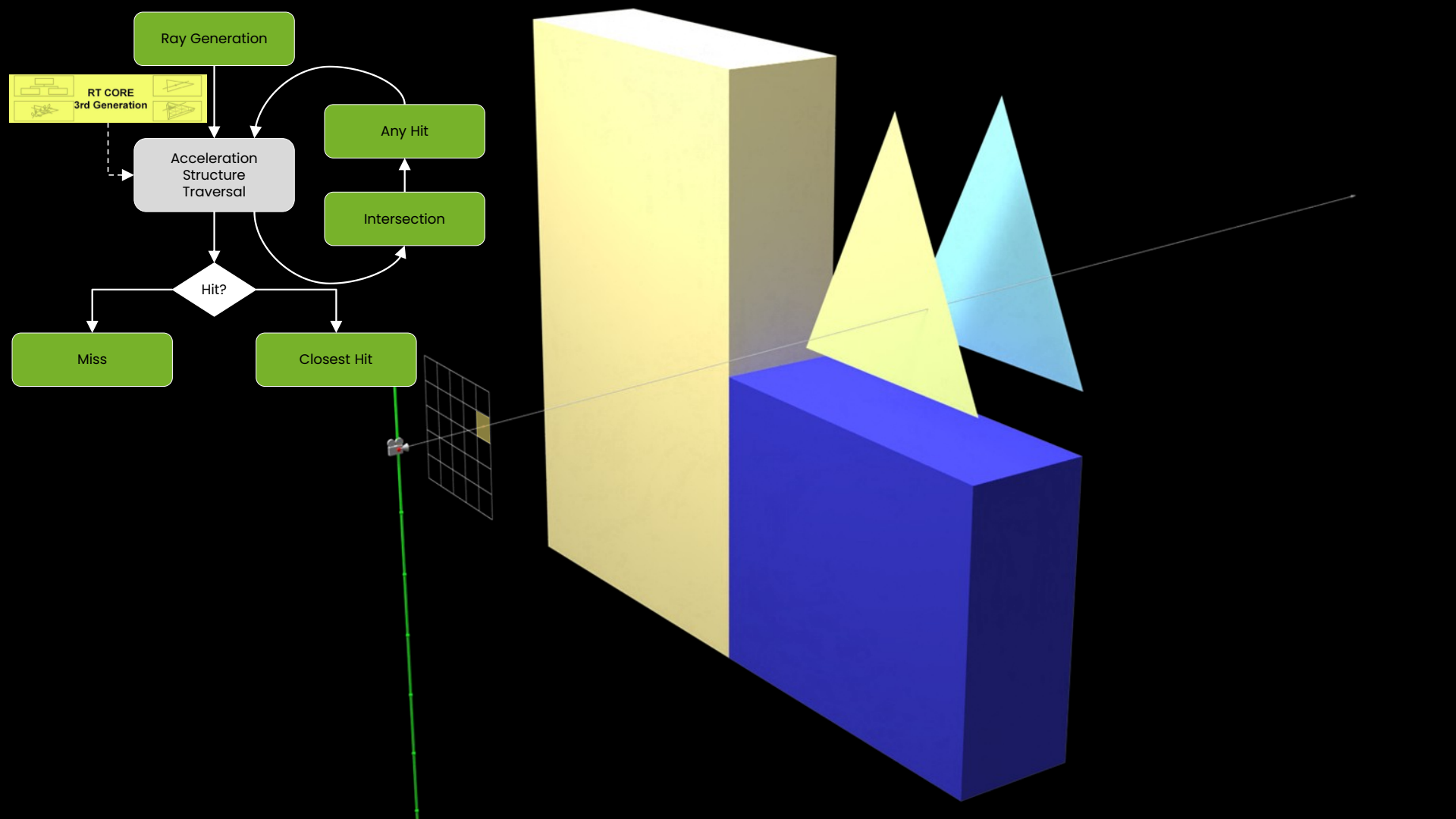

Ray Generation
RT CORE
3rd Generation
Any Hit
Acceleration
Structure
Traversal
Intersection
Hit?
Miss
Closest Hit

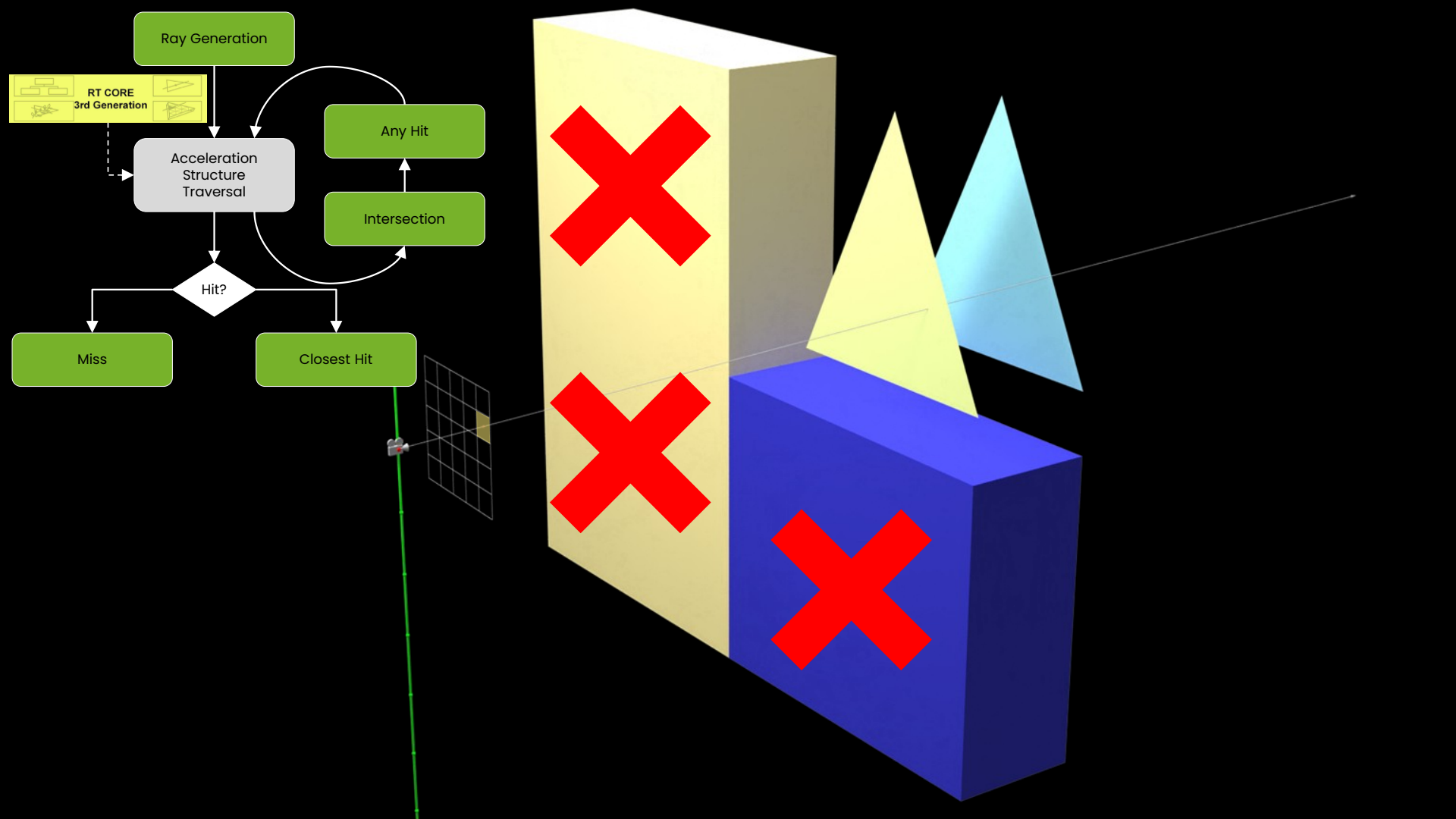

Ray Generation
RT CORE
3rd Generation
Acceleration
Structure
Traversal
Any Hit
Intersection
Hit?
Miss
Closest Hit

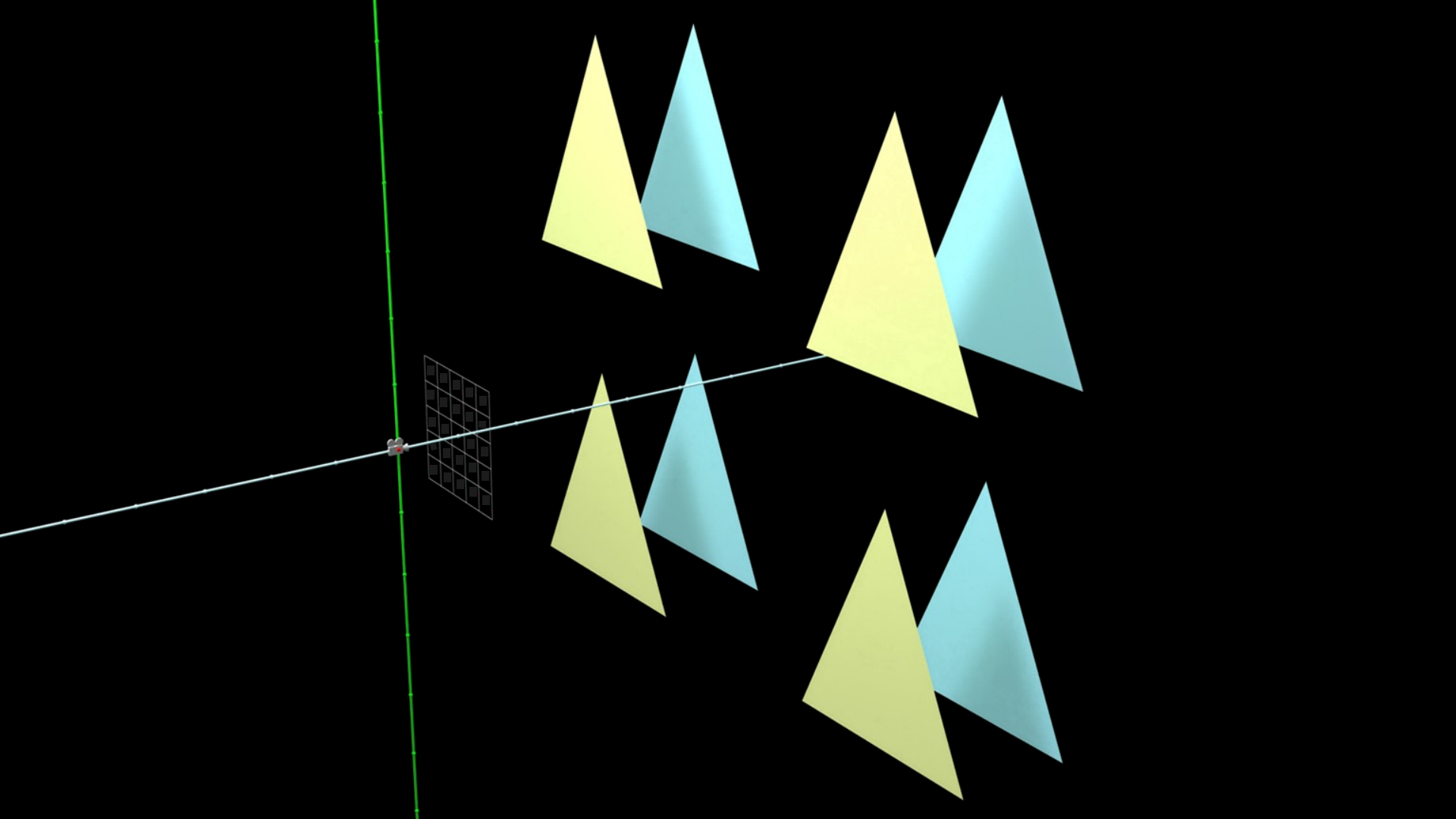

Ray Generation
RT CORE
3rd Generation
Any Hit
Acceleration
Structure
Traversal
Intersection
Hit?
Miss
Closest Hit


Ray Generation
RT CORE
3rd Generation
Acceleration
Structure
Traversal
Any Hit
Intersection
Hit?
Miss
Closest Hit


Ray Generation
RT CORE
3rd Generation
Any Hit
Acceleration
Structure
Traversal
Intersection
Hit?
Miss
Closest Hit

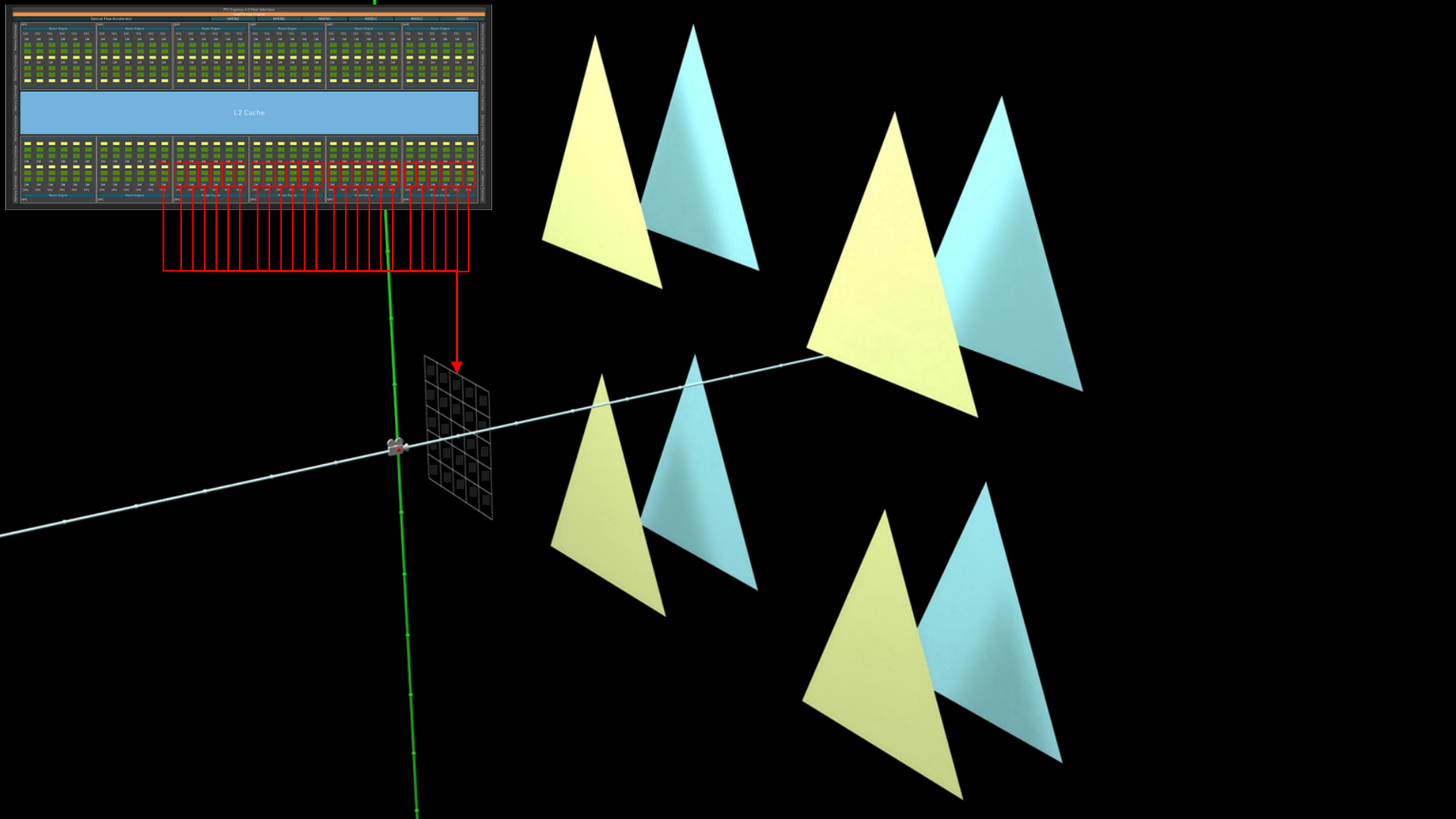

Ray Generation
RT CORE
3rd Generation
Any Hit
Acceleration
Structure
Traversal
Intersection
Hit?
Miss
Closest Hit

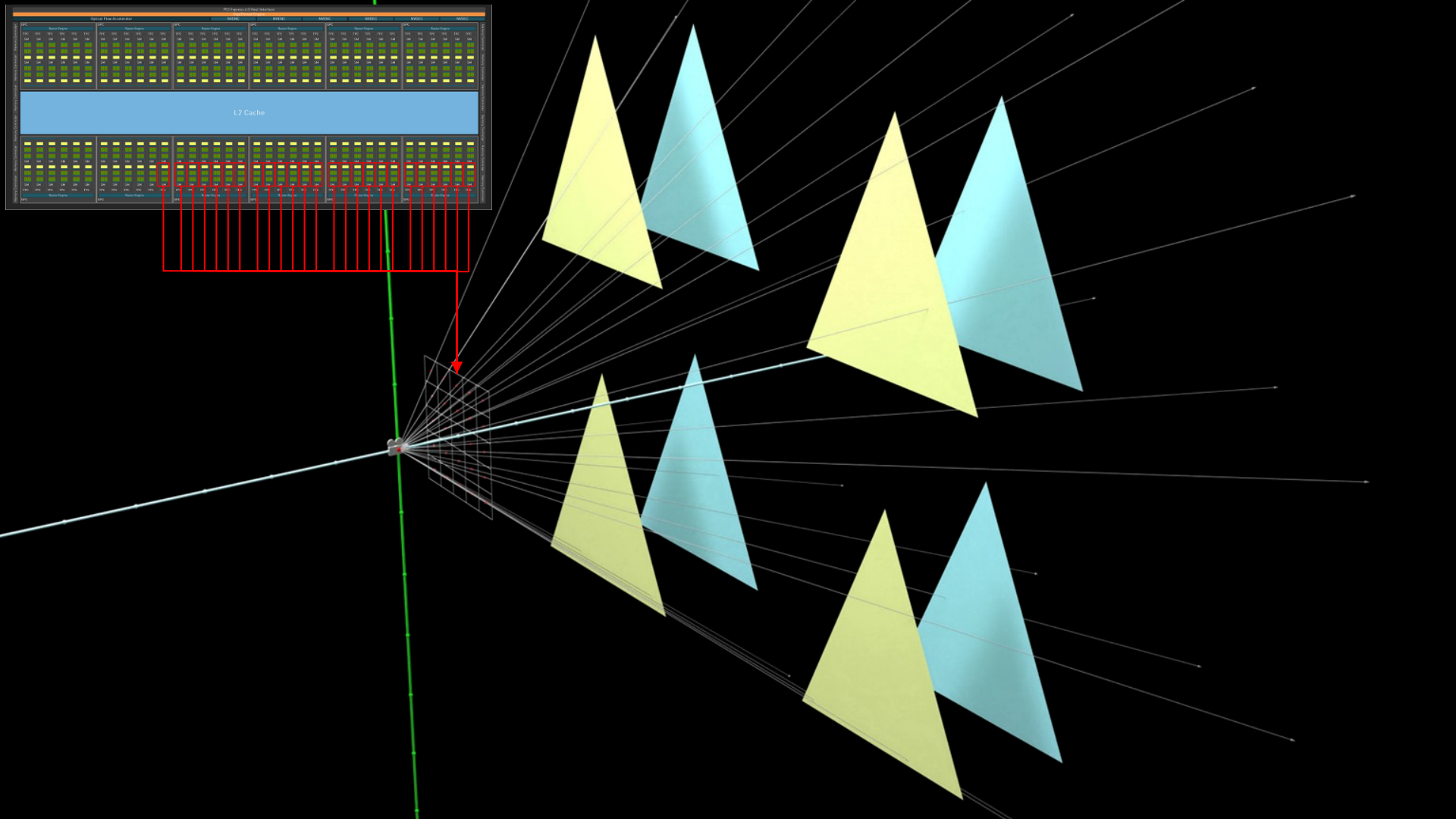

Ray Generation
RT CORE
3rd Generation
Acceleration
Structure
Traversal
Any Hit
Intersection
Hit?
Miss
Closest Hit



L2 Cache

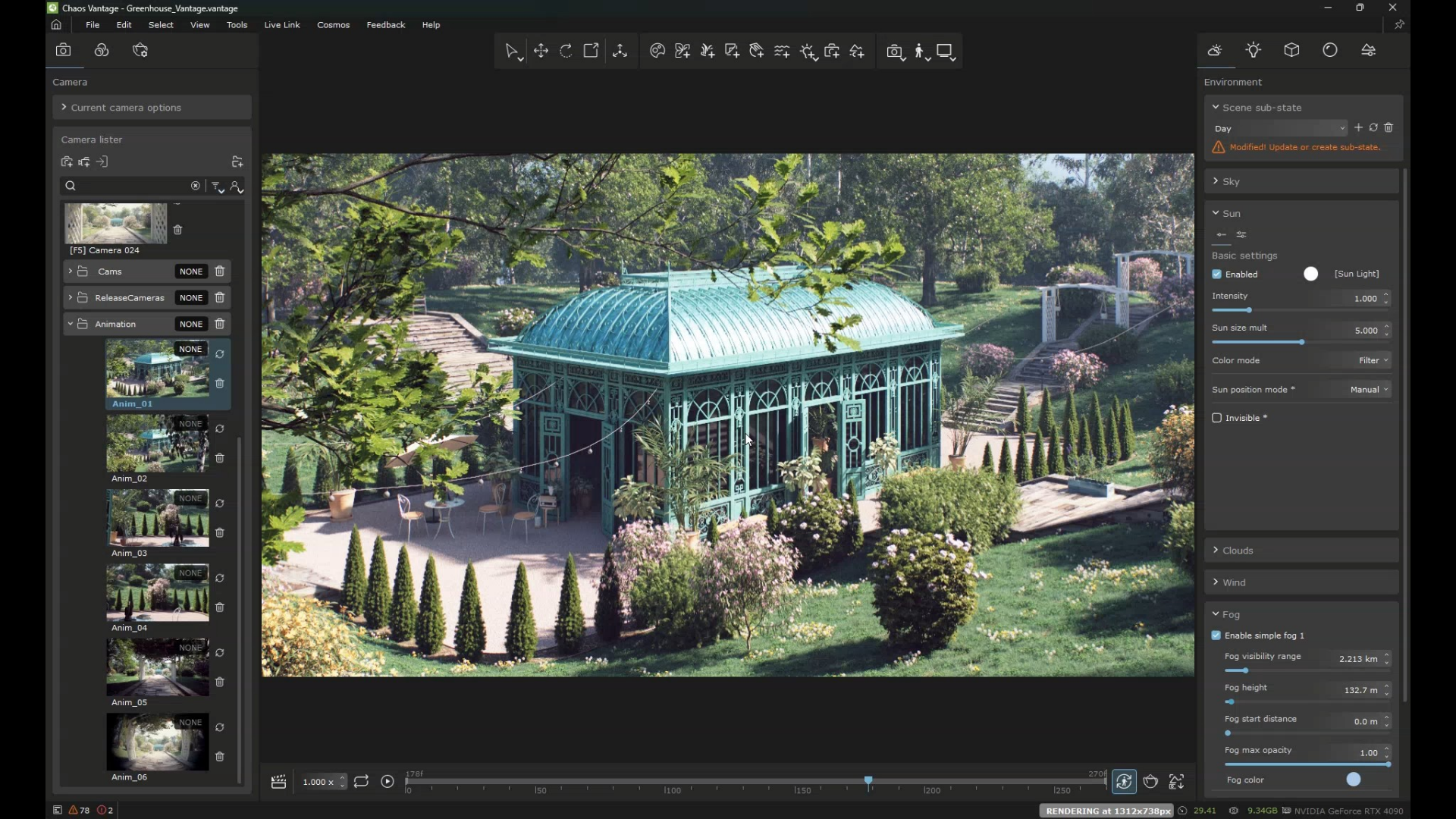
L2 Cache

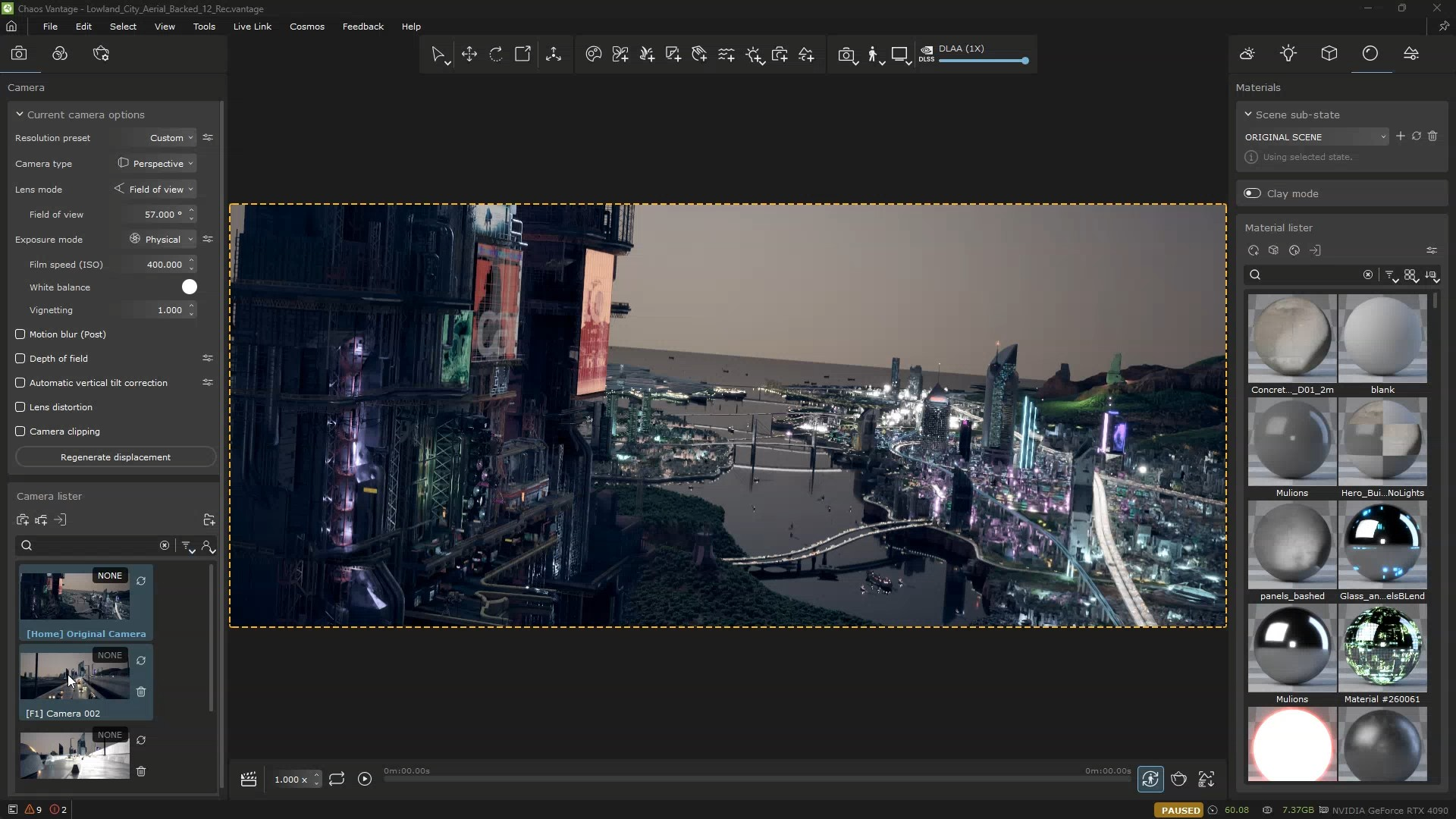

L2 Cache


L2 Cache

Lavina
2018

Vantage
2020


Chaos Vantage - Greenhouse_Vantage.vantage
File
Edit
Select
View
Tools
Live Link
Cosmos
Feedback
Help
Camera
Current camera options
Camera lister
[F5] Camera 024
Cams
NONE
ReleaseCameras
NONE
Animation
NONE
Anim_01
Anim_02
Anim_03
Anim_04
Anim_05
Anim_06
Environment
Scene sub-state
Day
Modified! Update or create sub-state.
Sky
Sun
Basic settings
Enabled
[Sun Light]
Intensity
1.000
Sun size mult
5.000
Color mode
Filter
Sun position mode *
Manual
Invisible *
Clouds
Wind
Fog
Enable simple fog 1
Fog visibility range
2.213 km
Fog height
132.7 m
Fog start distance
0.0 m
Fog max opacity
1.00
Fog color
1.000 x
178f
270f
RENDERING at 1312x738px
29.41
9.34GB
NVIDIA GeForce RTX 4090


Chaos Vantage - Lowland_City_Aerial_Backed_12_Rec.vantage
File
Edit
Select
View
Tools
Live Link
Cosmos
Feedback
Help
DLAA (1X)
Camera
Current camera options
Resolution preset
Custom
Camera type
Perspective
Lens mode
Field of view
Field of view
57.000 °
Exposure mode
Physical
Film speed (ISO)
400.000
White balance
Vignetting
1.000
Motion blur (Post)
Depth of field
Automatic vertical tilt correction
Lens distortion
Camera clipping
Regenerate displacement
Camera lister
NONE
[Home] Original Camera
NONE
[F1] Camera 002
NONE
1.000 x
0m:00.00s
0m:00.00s
Materials
Scene sub-state
ORIGINAL SCENE
Using selected state.
Clay mode
Material lister
Concret..._D01_2m
blank
Mulions
Hero_Bui...NoLights
panels_bashed
Glass_an...elsBLend
Mulions
Material #260061
PAUSED
60.08
7.37GB
NVIDIA GeForce RTX 4090

Denoising

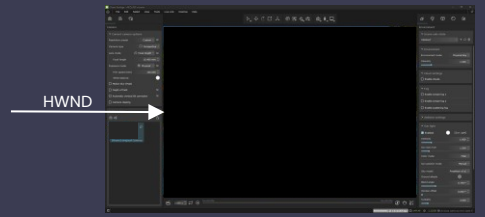
Original
Denoised

DLSS

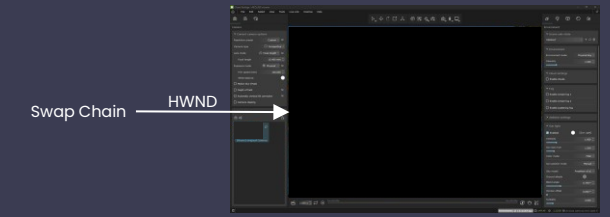
Render frame

Render frame

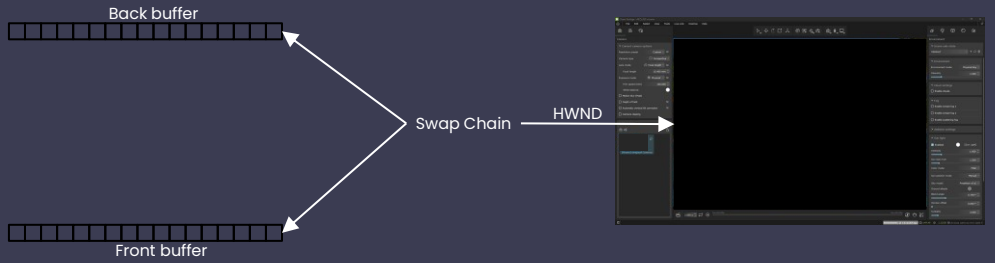
Render frame



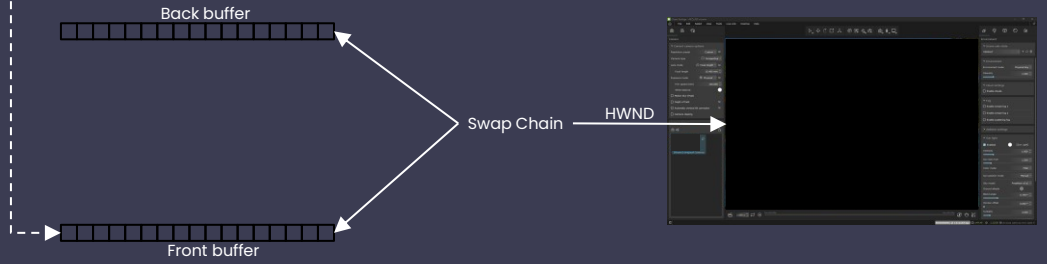
Render frame



Render frame

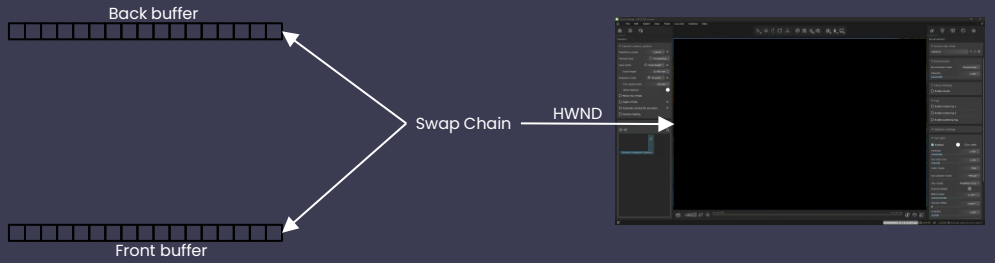


Render frame



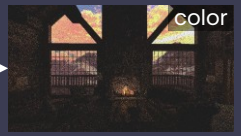
Render frame

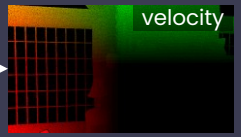
GPU Ray Tracing

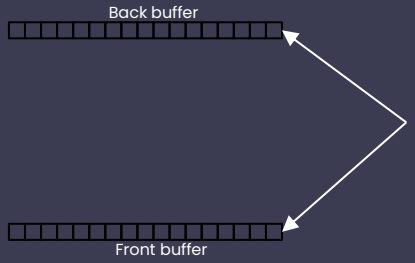


Render frame

GPU Ray Tracing



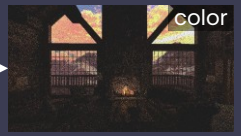


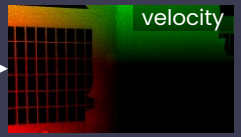


Render frame

GPU Ray Tracing

DLSS 3.5 RR



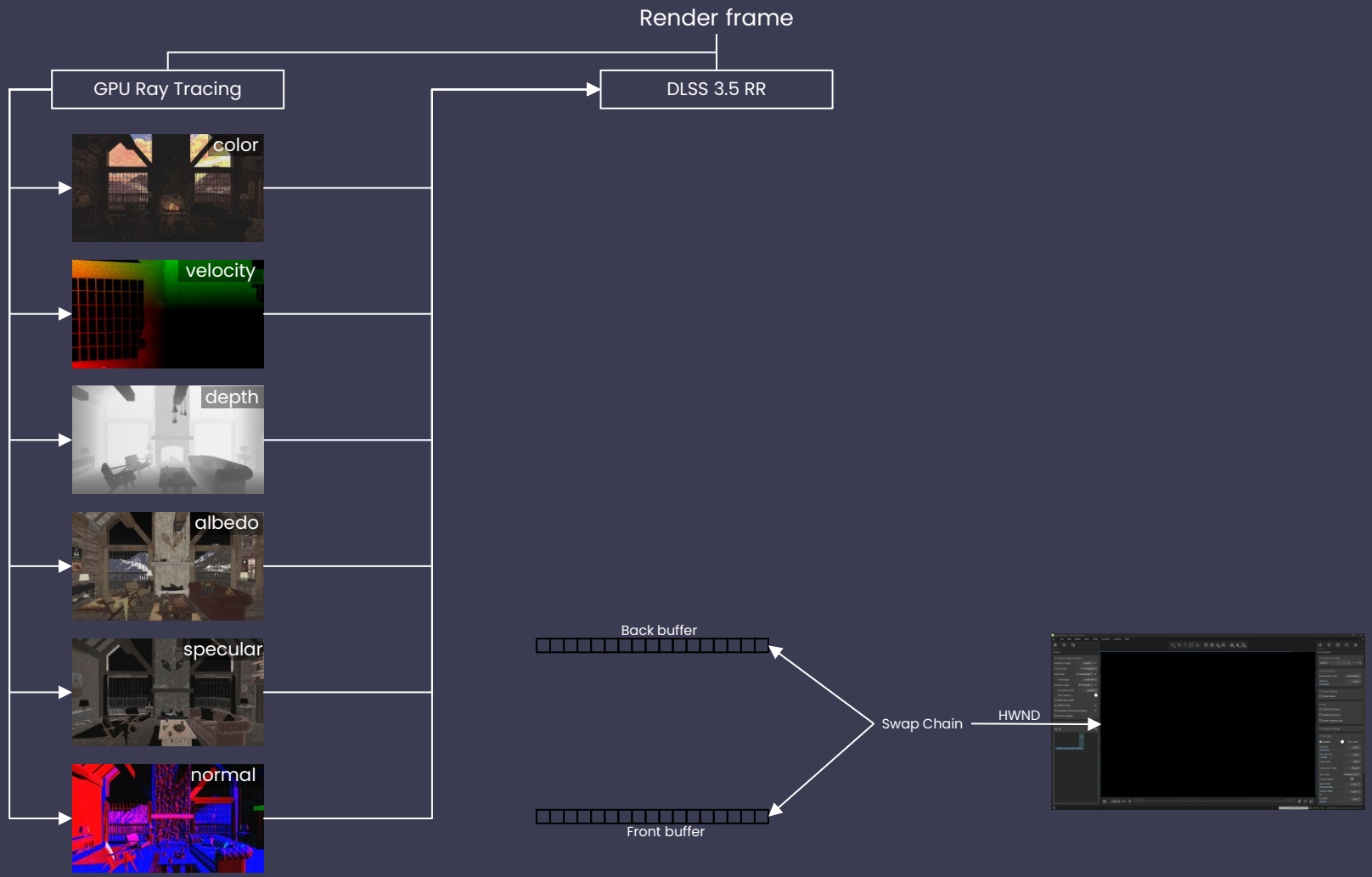


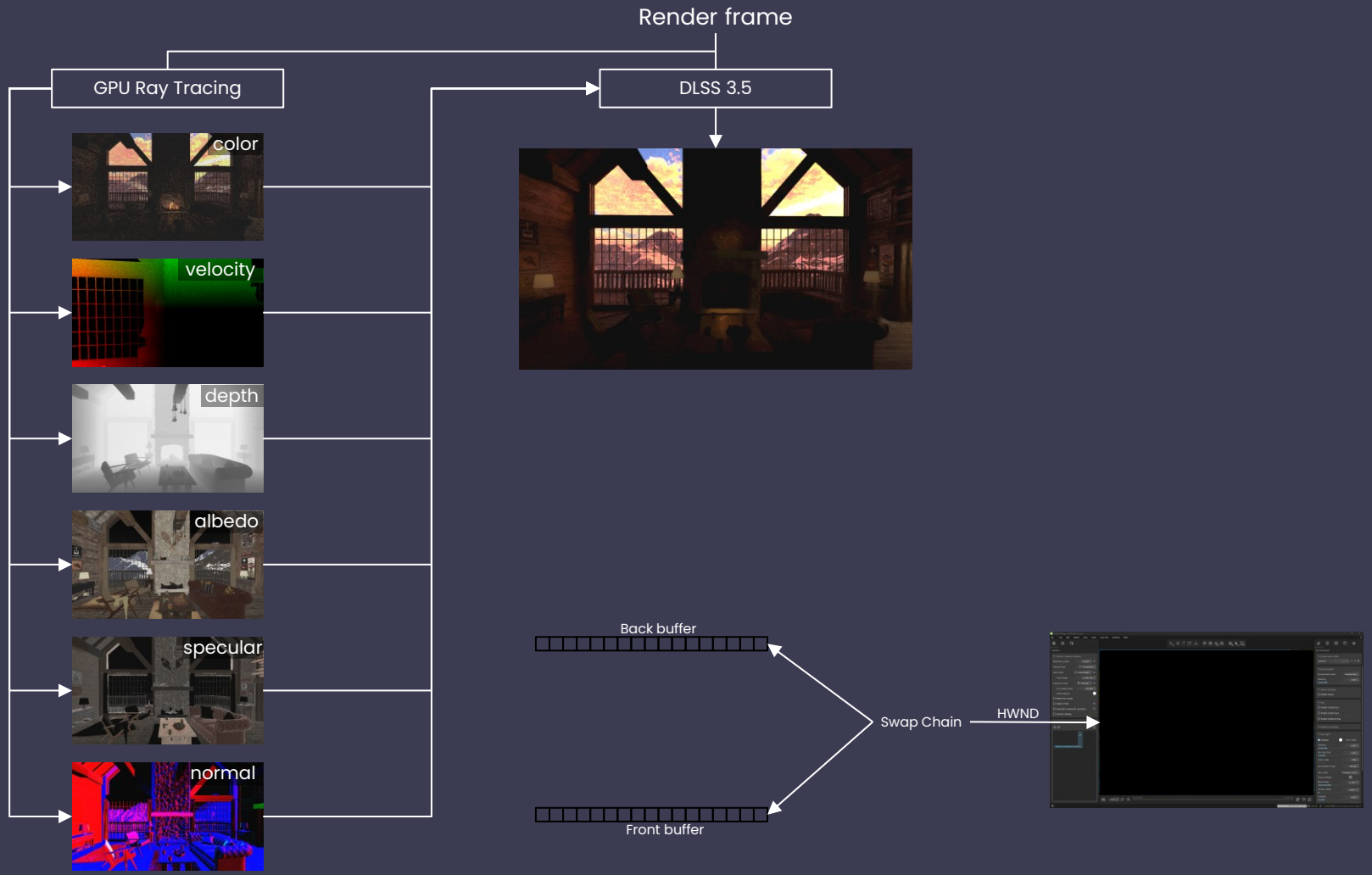
Back buffer

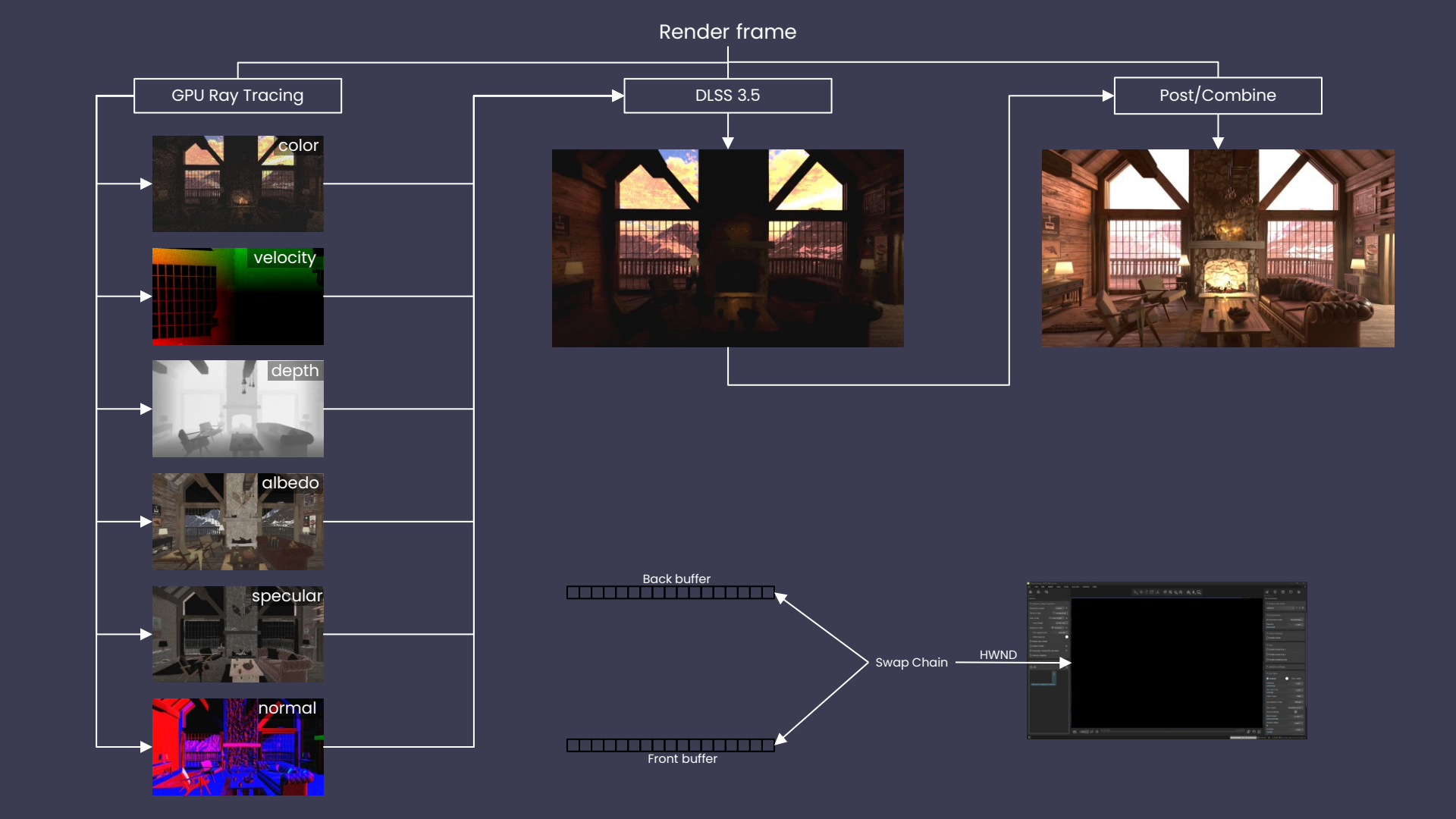
Swap Chain

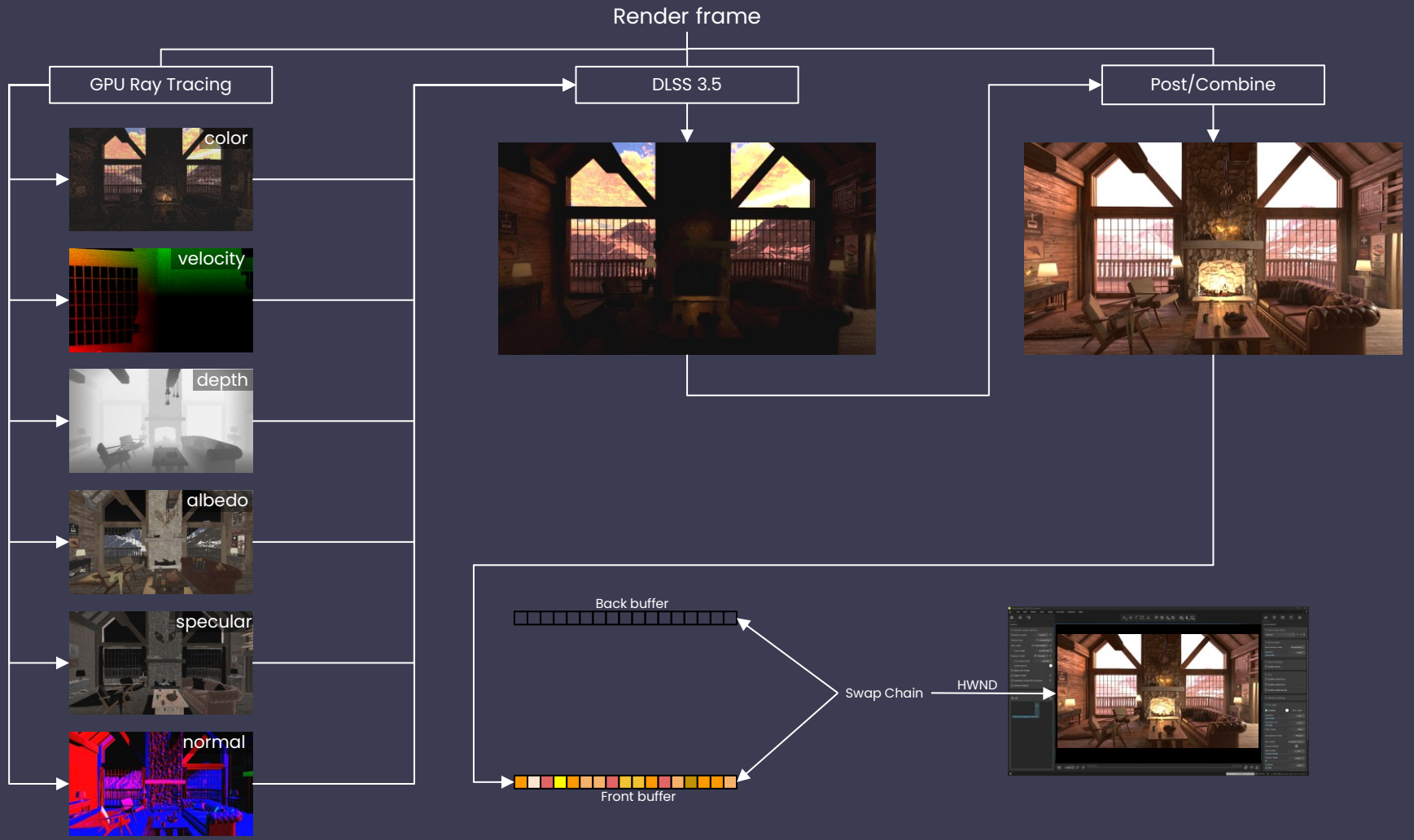
HWND

Front buffer

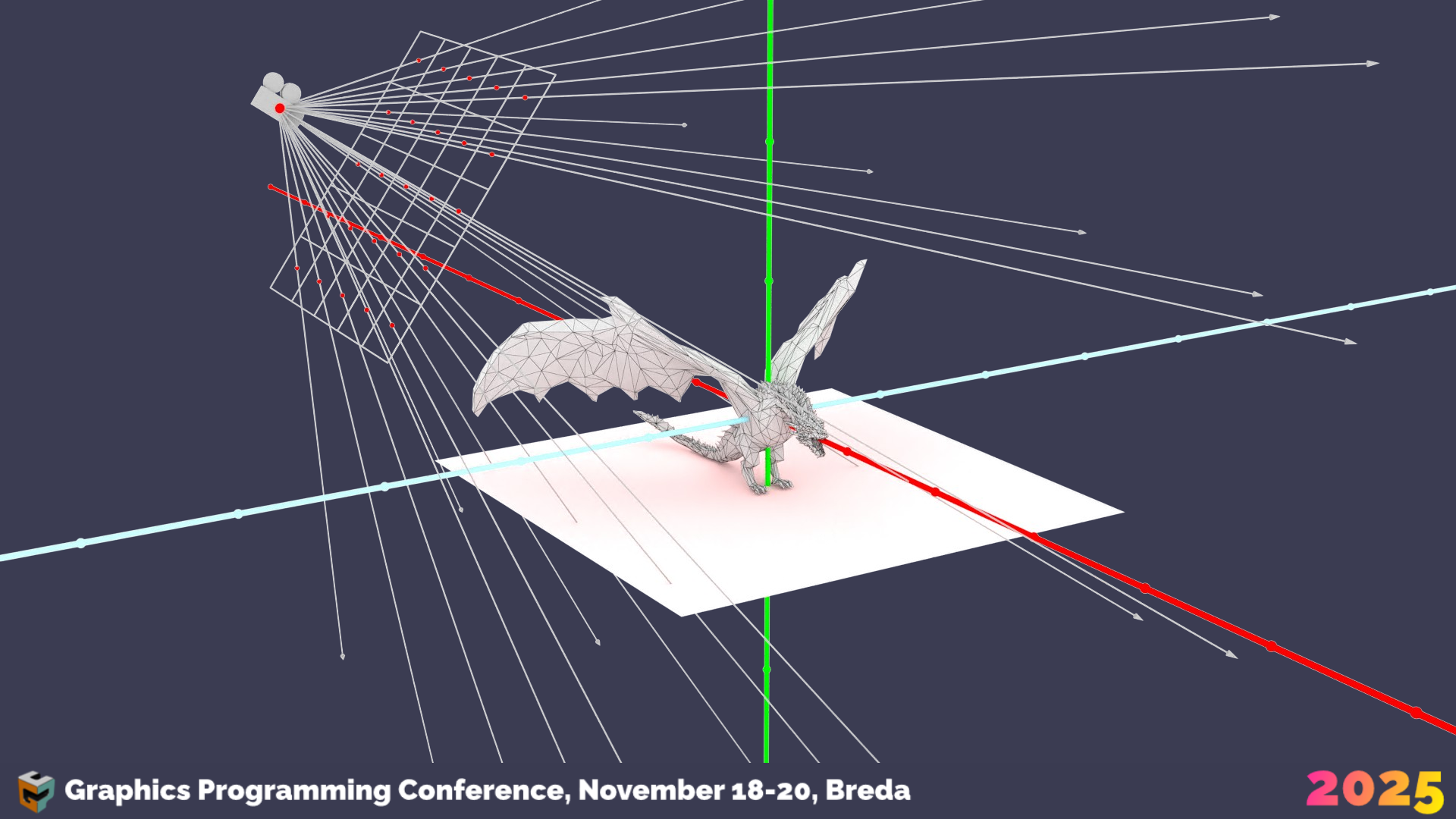

Render frame
GPU Ray Tracing
DLSS 3.5 RR
color
velocity
depth
albedo
specular
normal
Back buffer
Swap Chain
HWND
Front buffer

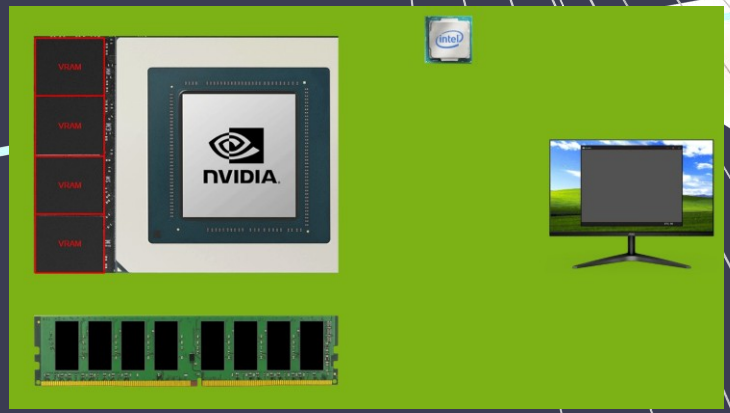

Render frame
GPU Ray Tracing
DLSS 3.5
color
velocity
depth
albedo
specular
normal
Back buffer
Swap Chain
HWND
Front buffer

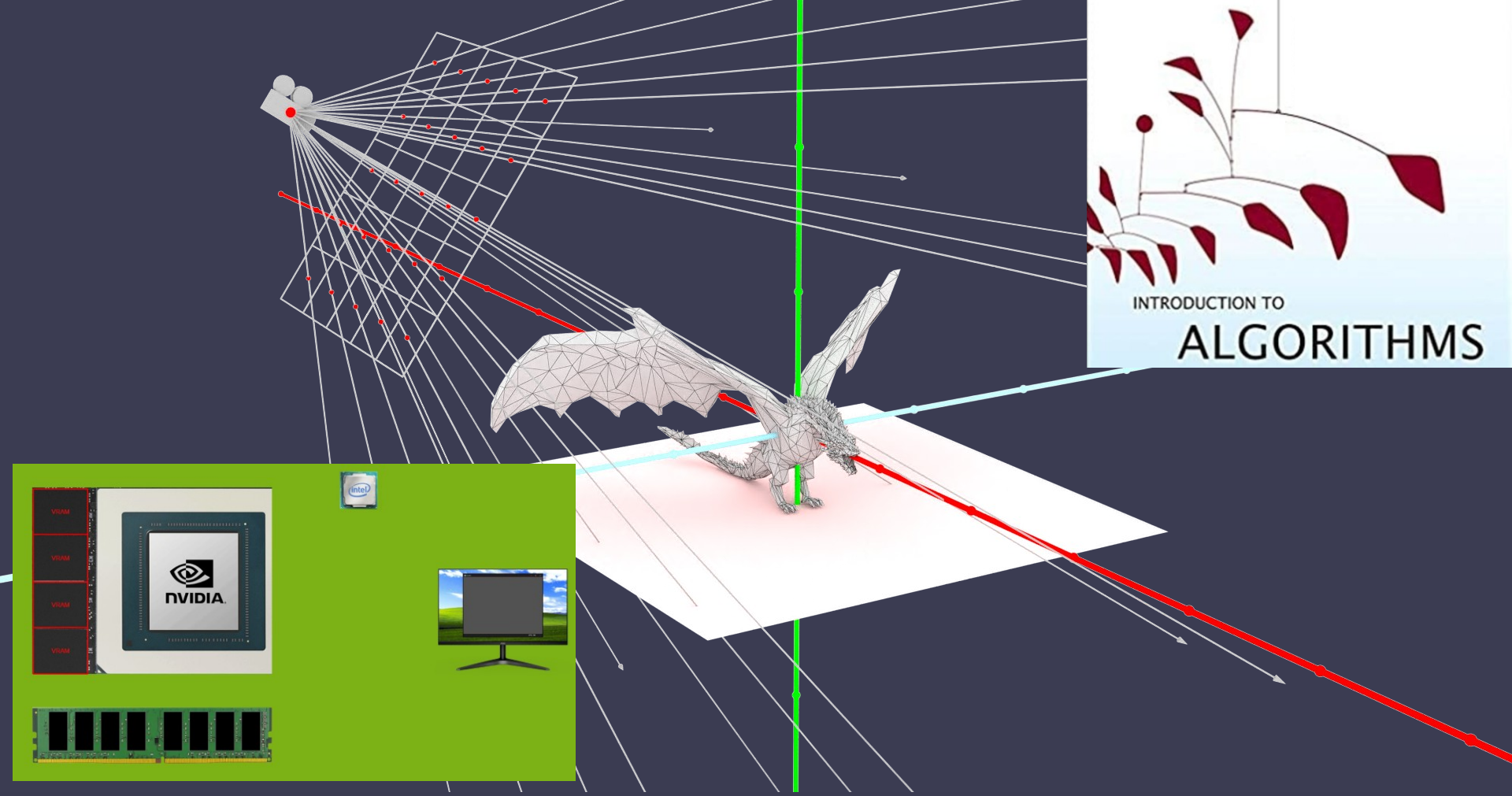

Render frame
GPU Ray Tracing
DLSS 3.5
Post/Combine
color
velocity
depth
albedo
specular
normal
Back buffer
Swap Chain
HWND
Front buffer

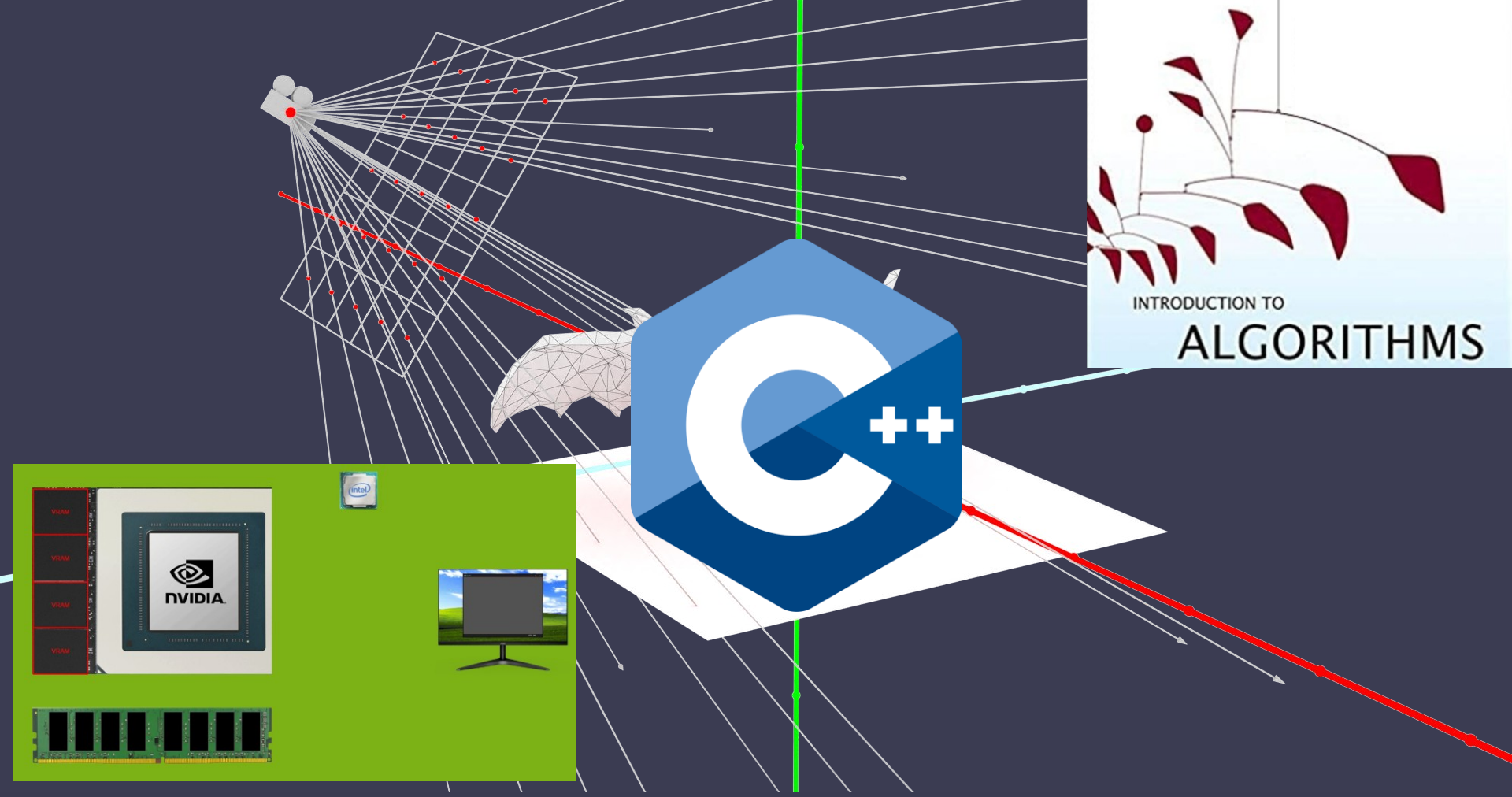

Render frame
GPU Ray Tracing
DLSS 3.5
Post/Combine
color
velocity
depth
albedo
specular
normal
Back buffer
Swap Chain
HWND
Front buffer

Chaos Camp




VRAM
VRAM
VRAM
VRAM
NVIDIA


INTRODUCTION TO
ALGORITHMS
VRAM
VRAM
VRAM
VRAM
NVIDIA
intel


INTRODUCTION TO
ALGORITHMS
C++
NVIDIA
Graphics Programming Conference, November 18-20, Breda
2025

Thank you!

chaos