UE4 tools for open world games

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Overview

- Level streaming
- World composition
- World origin rebasing
- Hierarchical LOD
- Navigation mesh

Level streaming

- Each world has at least one level (Persistent Level)
- Designers can manually add sub-levels
- Each sub-level stored in a separate package
- Sub-level is just a group of actors
- All level streaming settings stored in the Persistent Level
- Becomes bottleneck for editing

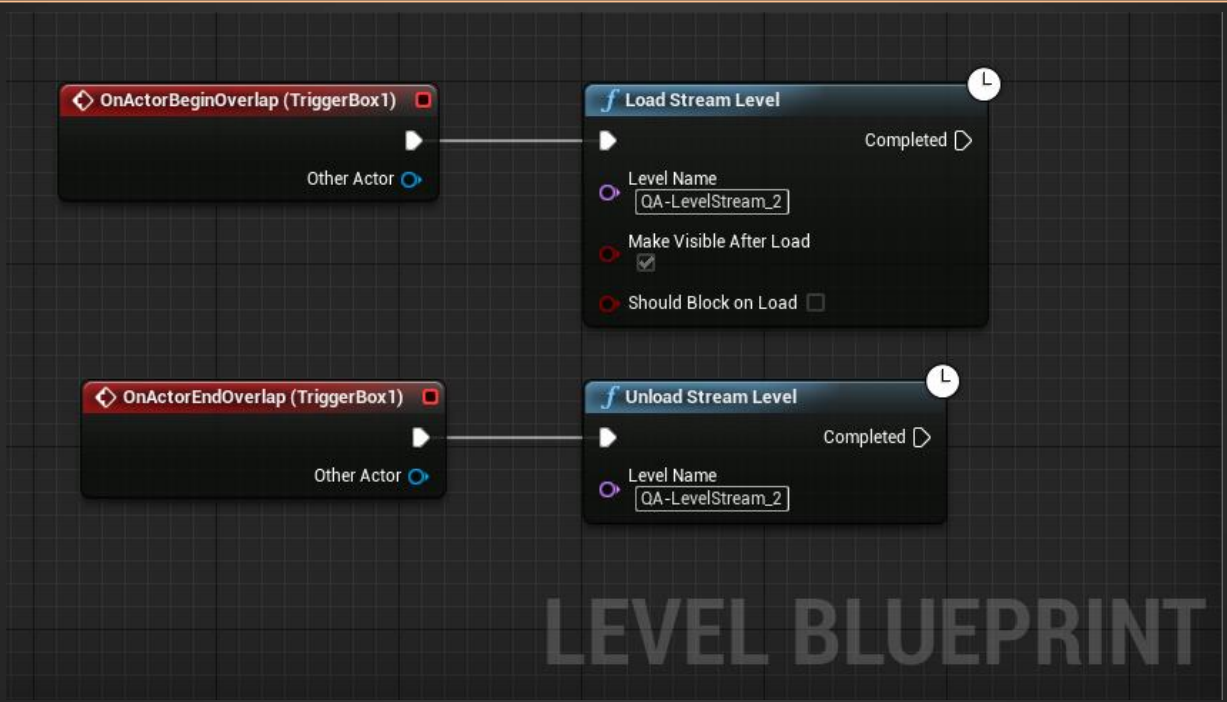
Level streaming

- Editor loads all sub-levels, regardless of streaming settings
- Basically streaming works only during gameplay
- Levels browser allows basic operations
  - Hiding/showing sub-levels
  - Locking actors
  - Assigning streaming volumes
  - Applying transformation to sub-levels

Level streaming

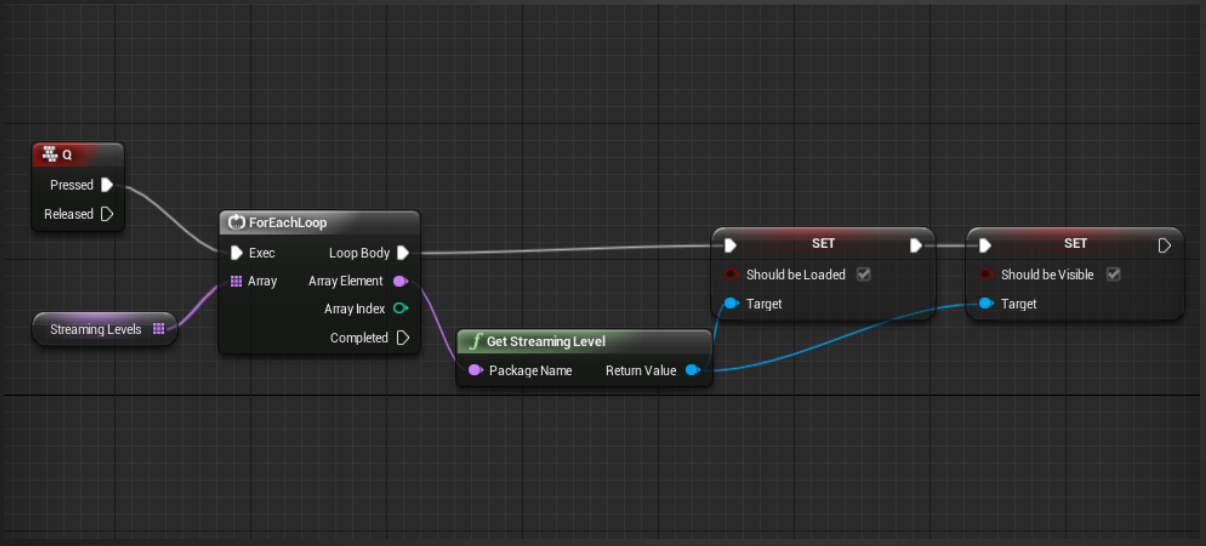
- Two types of level streaming strategy
- “Always Loaded” type
  - Fully loaded before gameplay begins
  - Mostly used as tool for collaborative map editing
- “Blueprint” type
  - User controlled conditions for loading and unloading
  - Can be used with blueprint scripting or Level Streaming Volumes

Scripted level streaming



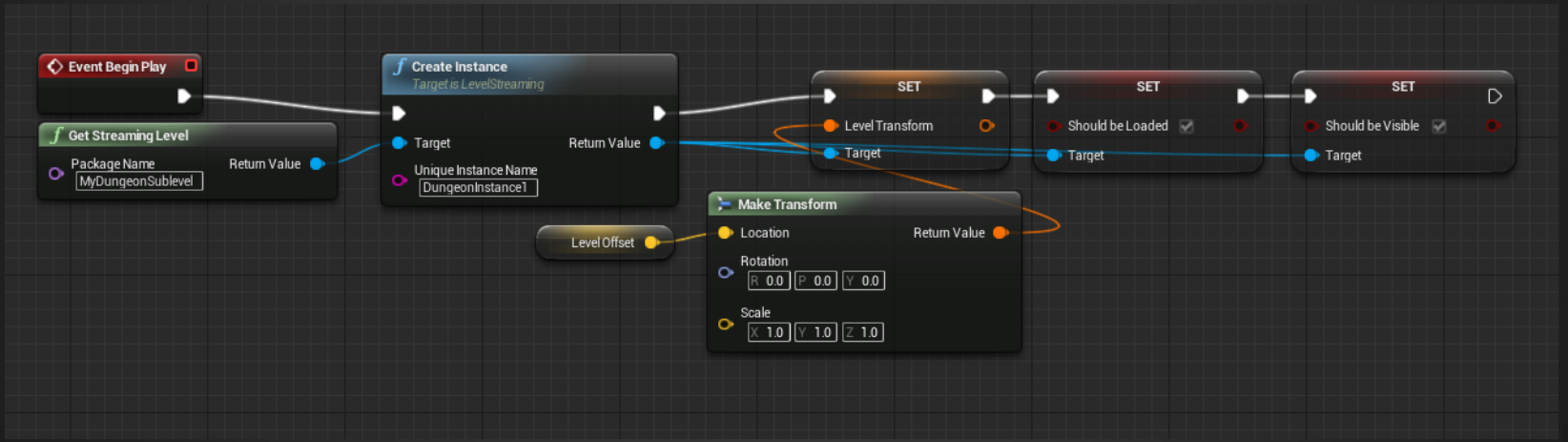
Scripted level streaming

- ‘Get Streaming Level’ blueprint node
- For more flexible control over level streaming



Level instancing

- Multiple copies of the sub-level loaded under different names
- Fortnite uses instancing to create procedural worlds



Level streaming

Level streaming has two main steps

1. Loading level package into memory
    1. Uses separate thread in latest UE4 versions (4.7, only in cooked build)
    2. Can do a blocking load on user request
    3. Supports cancelation
2. Registering objects in the game world
    1. Always happen in the game thread
    2. Work distributed over several frames

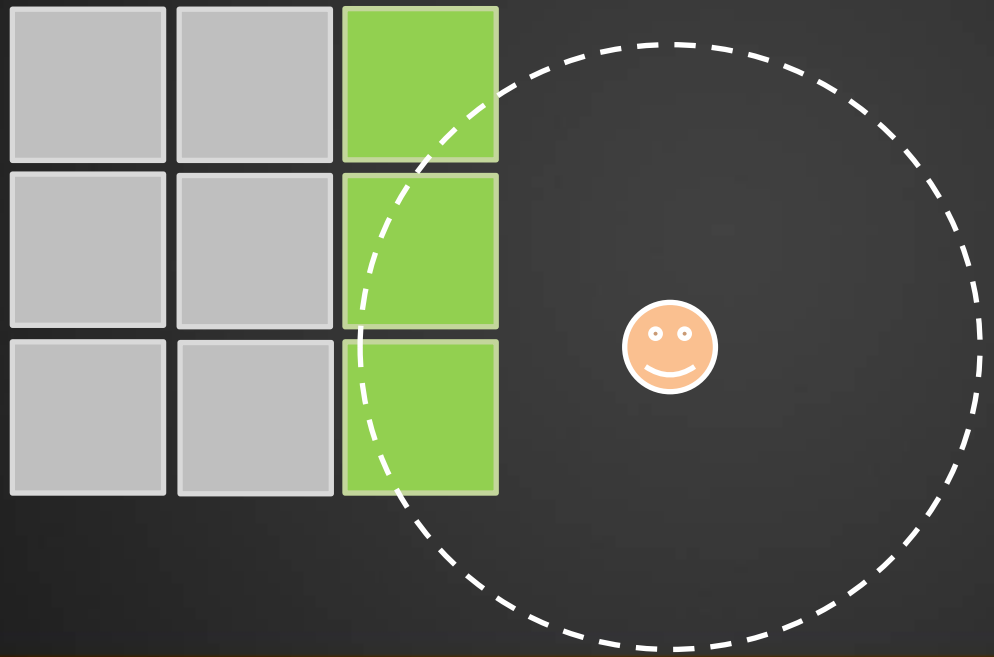
World composition

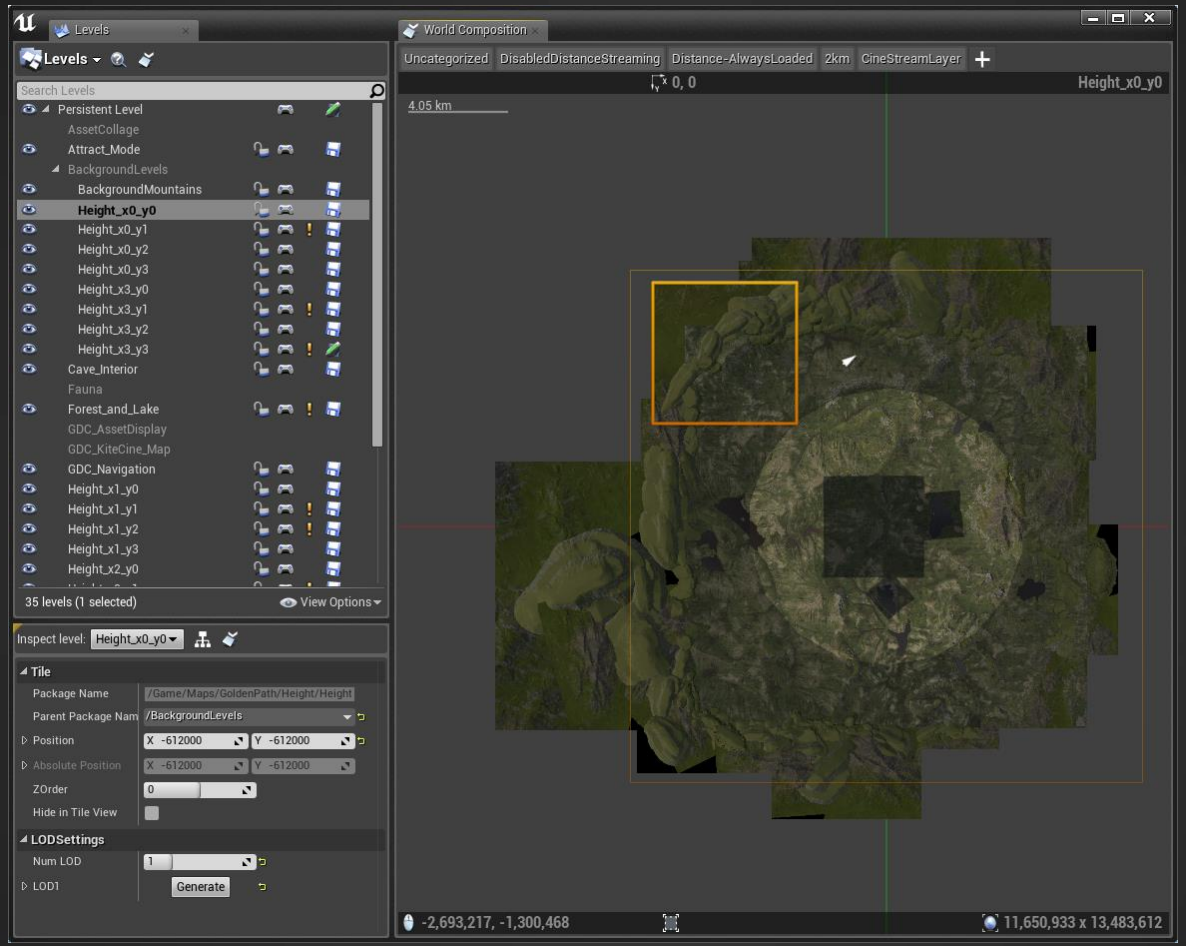
- Feature to simplify management of big worlds in UE4
- Auto-discovers all sub-levels in your work folder
- Does not stores any data in the persistent level
- Uses distance streaming by default
- Auto-calculates bounding box for each sub-level
- On demand loads sub-levels in the Editor

Distance based streaming

- Subdivide your world into tiles
- Streams in/out sub-levels based on distance from camera
- Each sub-level can have their own distance settings.
  - Controlled by “layers”
- Exceptions for specific sub-levels as non-distance streaming
  - Those sub-levels can be managed in blueprints

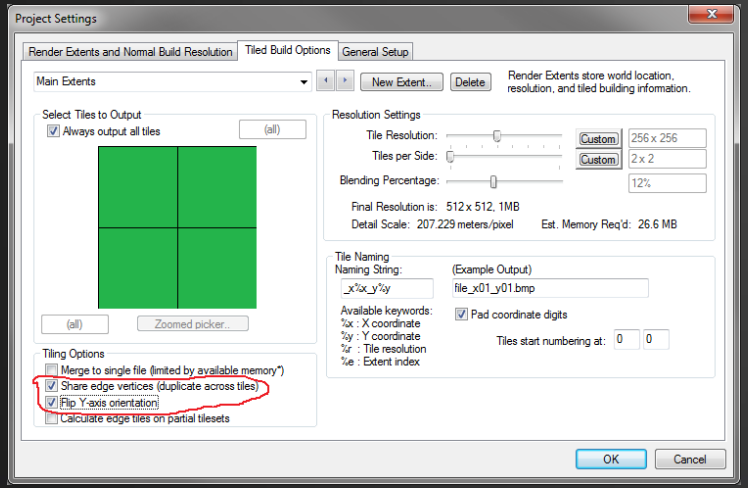
Distance based streaming

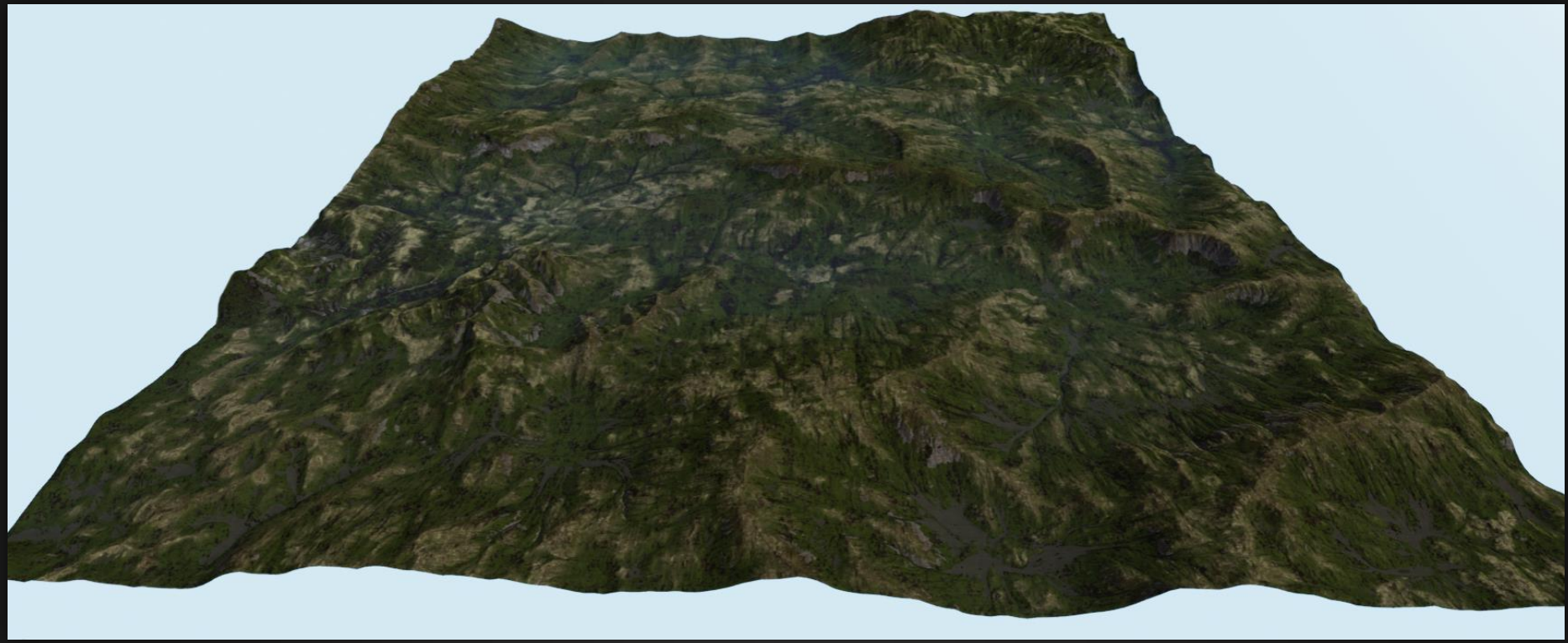



Levels
Levels
Search Levels
Persistent Level
AssetCollage
Attract_Mode
BackgroundLevels
BackgroundMountains
Height_x0_y0
Height_x0_y1
Height_x0_y2
Height_x0_y3
Height_x3_y0
Height_x3_y1
Height_x3_y2
Height_x3_y3
Cave_Interior
Fauna
Forest_and_Lake
GDC_AssetDisplay
GDC_KiteCine_Map
GDC_Navigation
Height_x1_y0
Height_x1_y1
Height_x1_y2
Height_x1_y3
Height_x2_y0
35 levels (1 selected)
View Options
Inspect level:
Height_x0_y0
Tile
Package Name
/Game/Maps/GoldenPath/Height/Height
Parent Package Nam
/BackgroundLevels
Position
X -612000
Y -612000
Absolute Position
X -612000
Y -612000
ZOrder
0
Hide in Tile View
LODSettings
Num LOD
1
LOD1
Generate
World Composition
Uncategorized
DisabledDistanceStreaming
Distance-AlwaysLoaded
2km
CineStreamLayer
0, 0
Height_x0_y0
4.05 km
-2,693,217, -1,300,468
11,650,933 x 13,483,612

Tiled landscape import

- Allows to import huge landscapes into UE4
- Source data (heightmaps, weightmaps) should be subdivided into tiles
- World Machine has support for exporting data in tiled format





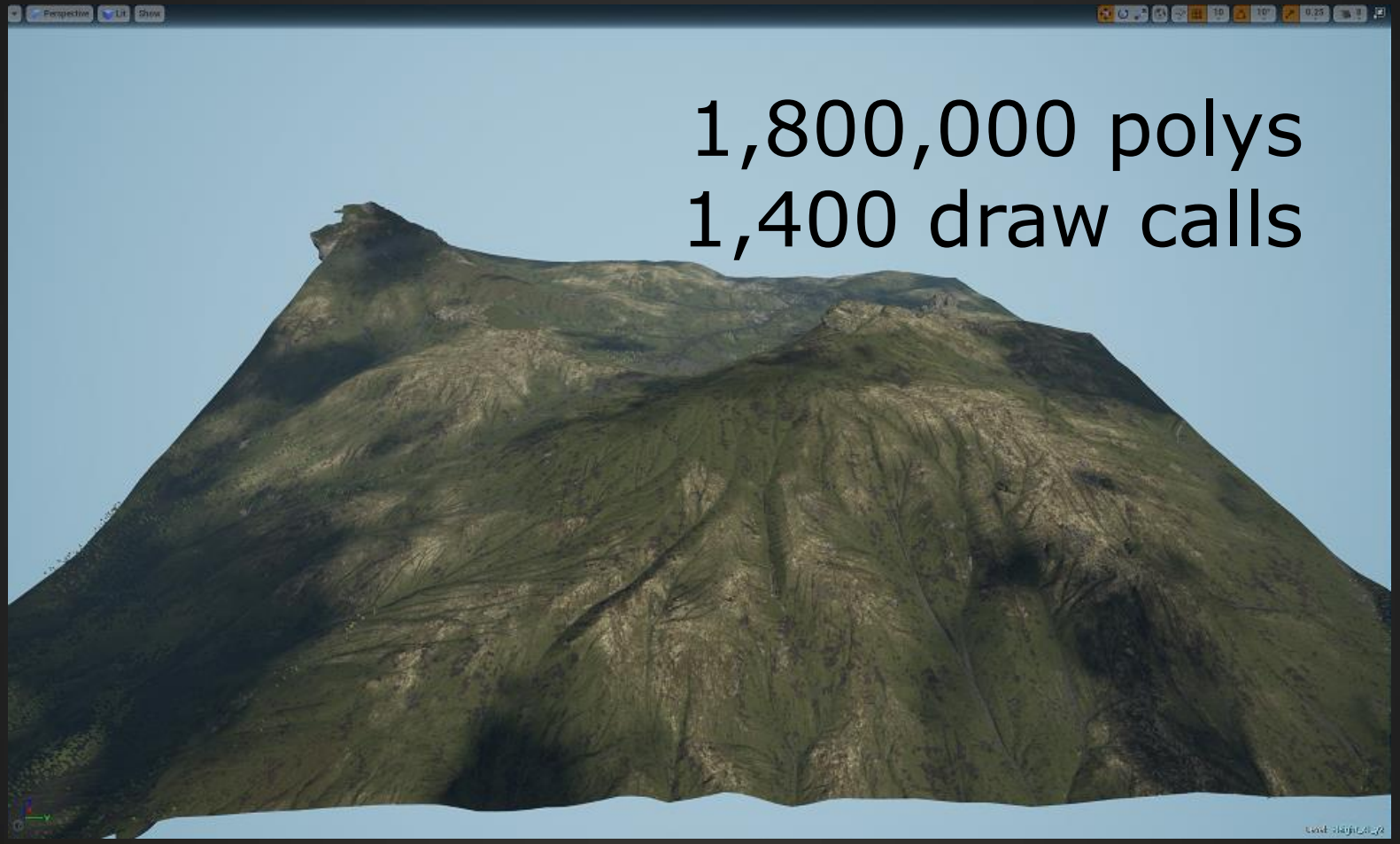
16 x 16 km, 1m resolution

Whole sub-level LOD

- World composition supports sub-level based LOD
- Basically based on distance to sub-level we replace it with another simplified version
- Each sub-level can have up to 4 simplified versions
- In most cases one is enough
- Switch between LOD sub-levels happens at single frame and is not noticeable in the distance
- Helps a lot with decreasing memory usage and improving perform ance, used in KiteDemo

Whole sub-level LOD

- World composition support auto-generation of sub-level LOD
- All landscape actors will be exported into static meshes
  - Landscape material rendered into texture and used for exported static mesh
- All static meshes will be merged together into one mesh proxy
  - All materials will be flattened and merged together as well
  - Requires Simplygon
- In result: a new sub-level with 2 static meshes in it


1,800,000 polys
1,400 draw calls


7,000 polys
4 draw calls

Even bigger worlds

- What if we want really huge worlds, beyond UE4 limitations?
- UE4 stores object absolute location as float vector (FVector)
- Floating point number range is irregular and gaps (Ulps) between numbers increasing with distance from zero
- After about 17 million floating point has less precision than integer numbers
- Replacing it with doubles will require major changes into engine

Even bigger worlds

1	1 meter	1.19E-07	119 nanometers	virus
10	10 meters	9.54E-07	.954 micrometers	e. coli bacteria
100	100 meters	7.63E-06	7.63 micrometers	red blood cell
1,000	1 kilometer	6.10E-05	61.0 micrometers	human hair width
10,000	10 kilometers	0.000977	.976 millimeters	toenail thickness
100,000	100 kilometers	0.00781	7.81 millimeters	size of an ant

Even bigger worlds

Usually we calculate position of a moving object like:

NewPosition = CurrentPosition + Velocity*DeltaTime

Will not work with small velocity far from origin

World origin rebasing

- UE4 has a feature to rebase current world origin to a new location
- Subtract an offset from zero origin to camera from all actors in the world
- Player camera moves to zero origin
- Performance depends on number of objects in the world
- Shifting couple thousand objects takes few milliseconds
- PhysX SDK has support for it PxScene::shiftOrigin(const PxVec3& shift)
- When enabled, engine automatically rebase origin when player camera 2km far

World origin rebasing downsides

- Unreal dedicated server does not support it. You will need your own server solution to deal with it
- More objects you have in the world, slower it will be, so you might need some gamep lay effect to hide it, like short loading screen
- Materials that use object absolute position will not work correctly, as object absolute position will be changed on rebasing

World origin rebasing

- Still, it’s a working feature
- Used in several space games
  - Eve: Valkyrie
  - Other unannounced titles

Level of details (LOD)

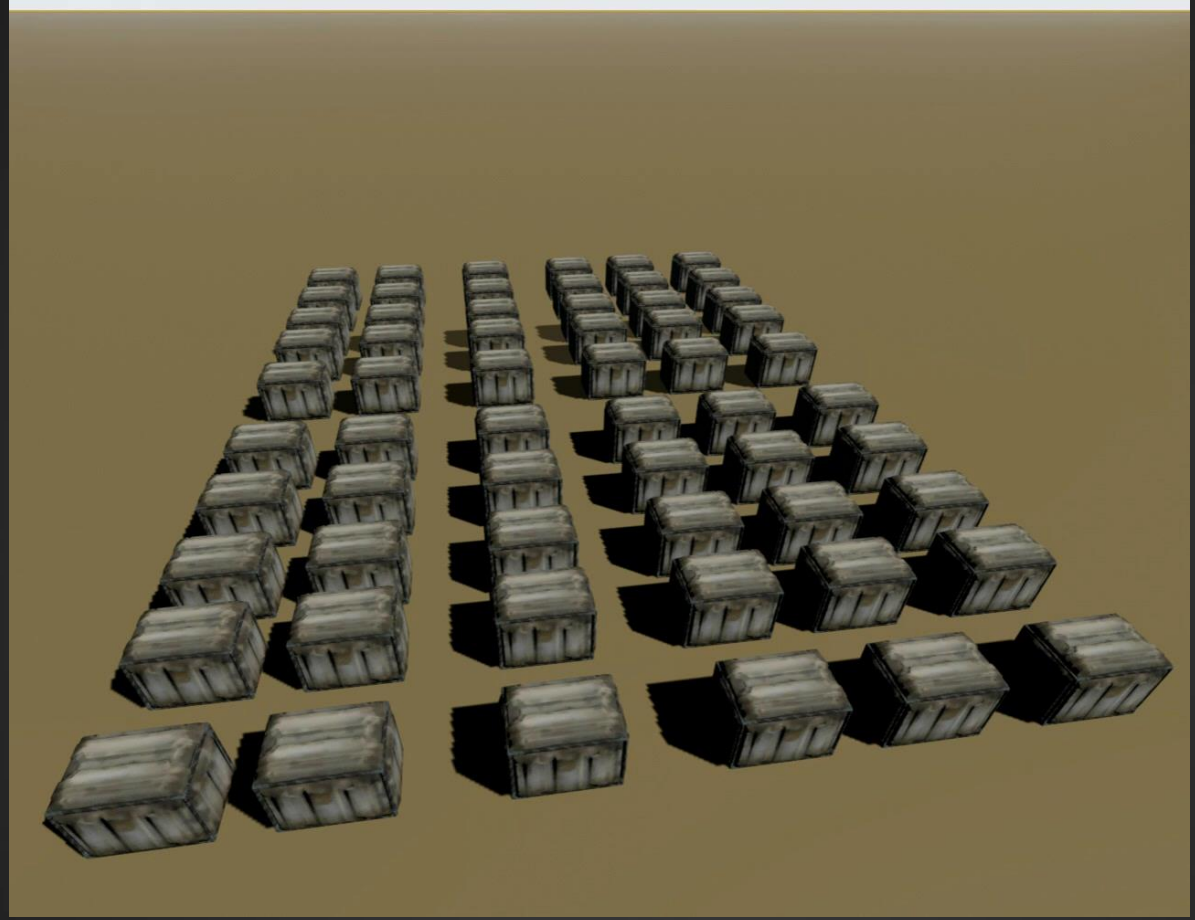
- Essential for open world games
- For static meshes replaces original mesh with simplified
- Usually switch happens depending on mesh size on the screen
- Landscape has automatic LOD
- Static meshes support up to 4 simplified versions
  - Requires Simplygon to generate them
  - Can use manually created meshes

Level of details (LOD)

- Does not reduces mesh count in the scene
- Mesh count has significant impact on performance
- Normally only reduces polygon count in the scene

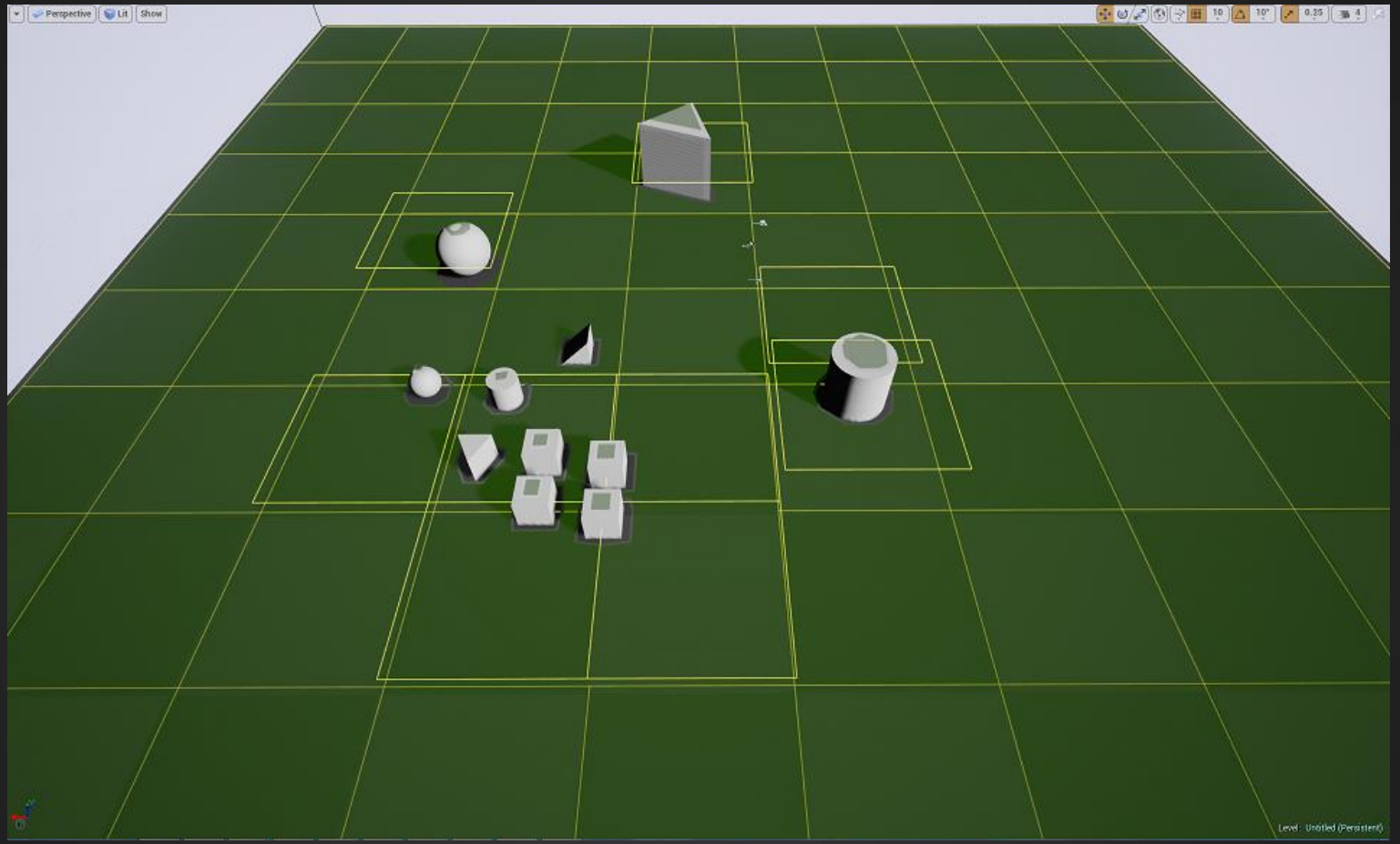
Hierarchical LOD

- With 4.8 we will add new feature Hierarchical LOD
- Aimed at reducing object count in your scene
- Uses clustering algorithm to group objects
- Each group of object than merged into one object
- Done in hierarchical way, so that you can have multiple levels
- Different settings for each level



Navigation mesh

- Modified Recast library to generate navigation mesh from geometry
- Navigation mesh is a regular grid of mesh tiles
- Mesh tile size can be changed, by default 10x10 meters
- Each mesh tile is independent of each other and can be added or removed on the fly
- Each mesh tile is generated on the background thread


Perspective
Lit
Show
Level : Untitled (Persistent)

Dynamic navigation mesh

- Holds a copy of all navigable geometry
- Can update navigation mesh on the fly
- Not suitable for open worlds, up to gigabytes of required memory
- Used in Fortnite, to support procedural world

Static navigation mesh

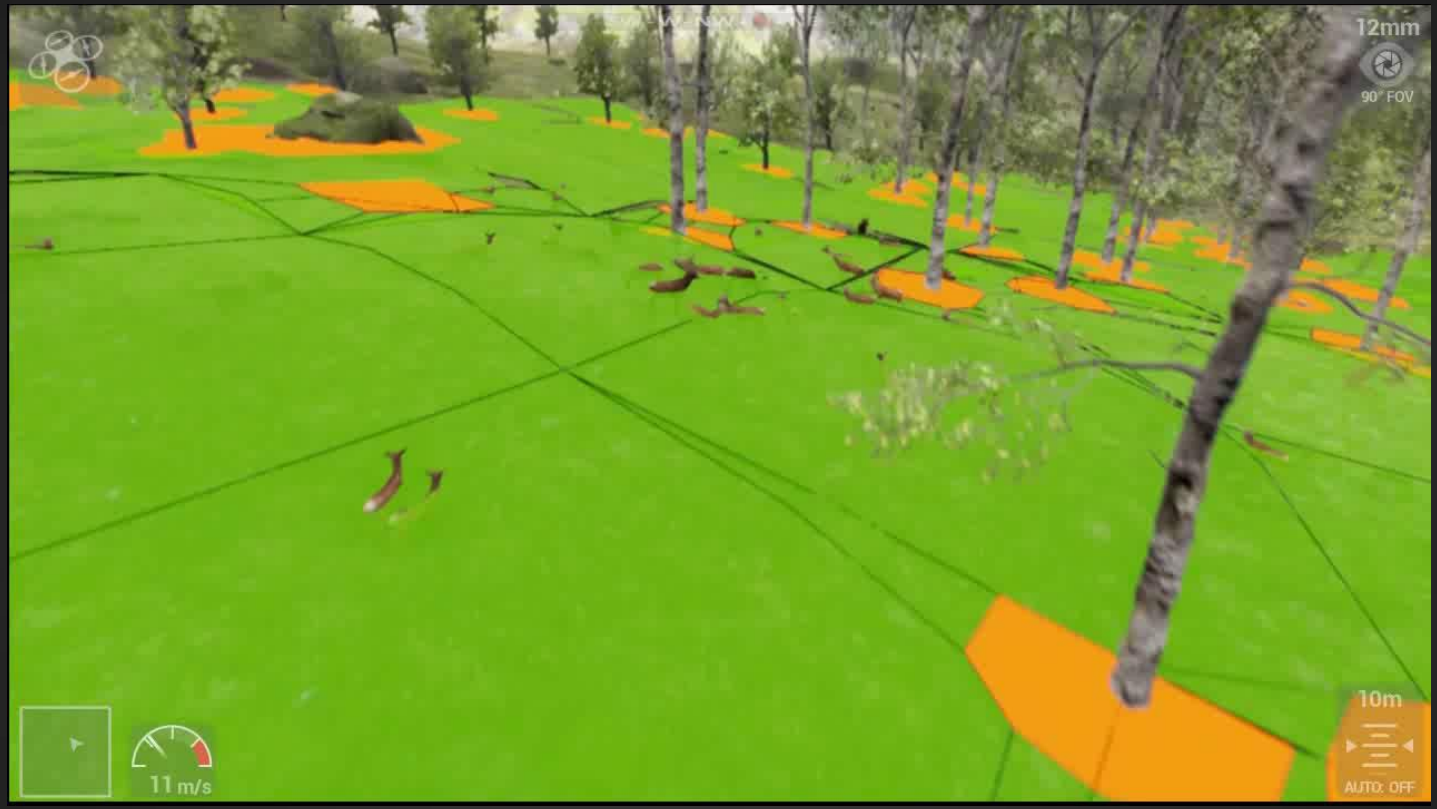
- Generate navigation mesh in the Editor and serialize it
- Does not support modification at game runtime
- Lowest memory requirements
- Supports streaming

Semi-dynamic navigation mesh

- Coming in 4.8
- Almost the same as static navigation mesh
- Does not support updates from geometry
- Updates navigation using navigation modifiers
- Has little memory overhead over static navigation mesh
- Supports streaming
- Recommended for open world games

Lazy-dynamic navigation mesh

- Fully dynamic navigation mesh
- Generates mesh tiles only around navigation invokers
- Does not hold copy of all world geometry
- On demand exports world geometry, in background thread
- We used it in KiteDemo for deers


12mm
90° FOV
10m
AUTO: OFF
11 m/s

Questions?