XeSS - High Quality Super Sampling from iGPU to dGPU

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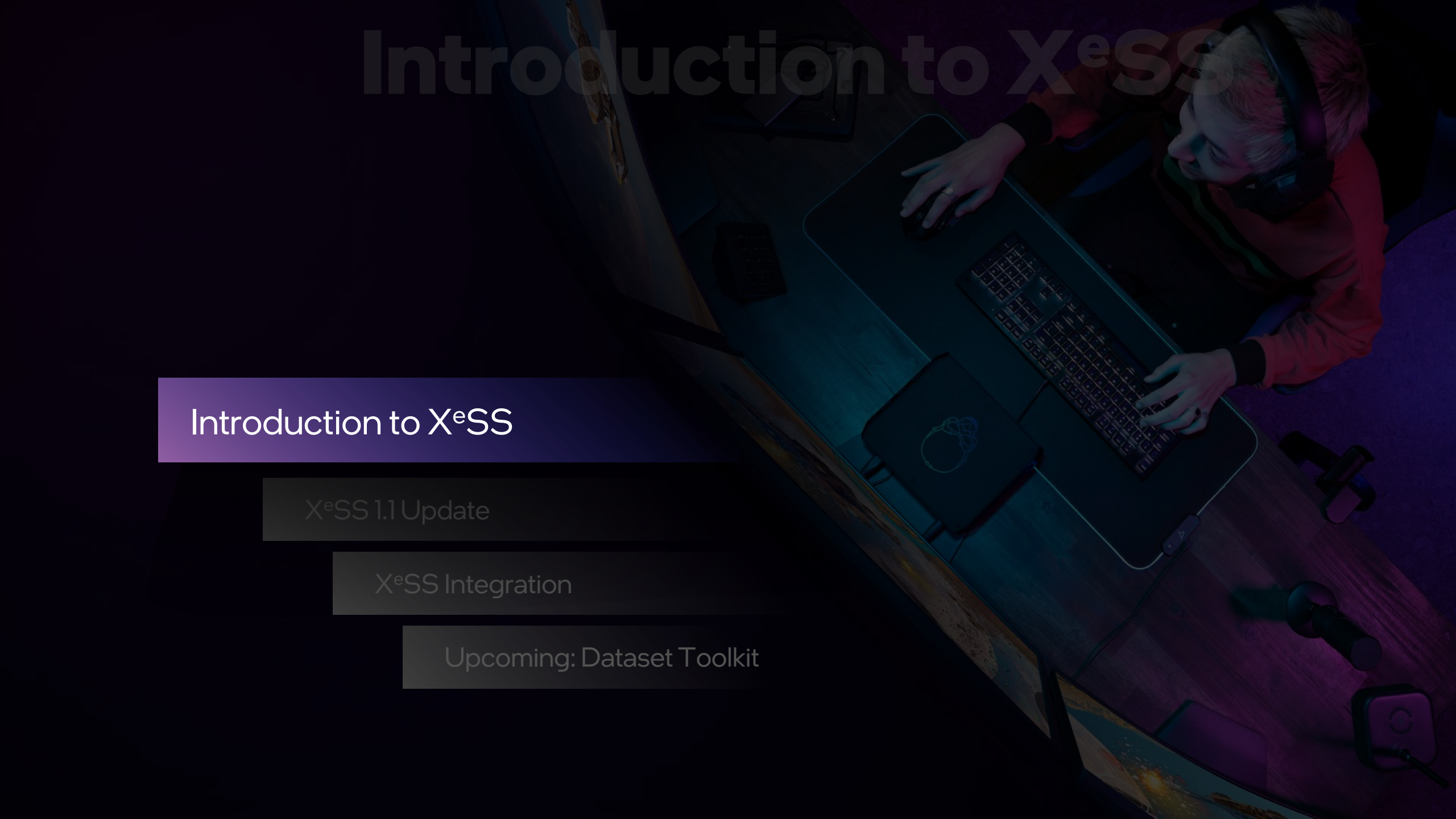
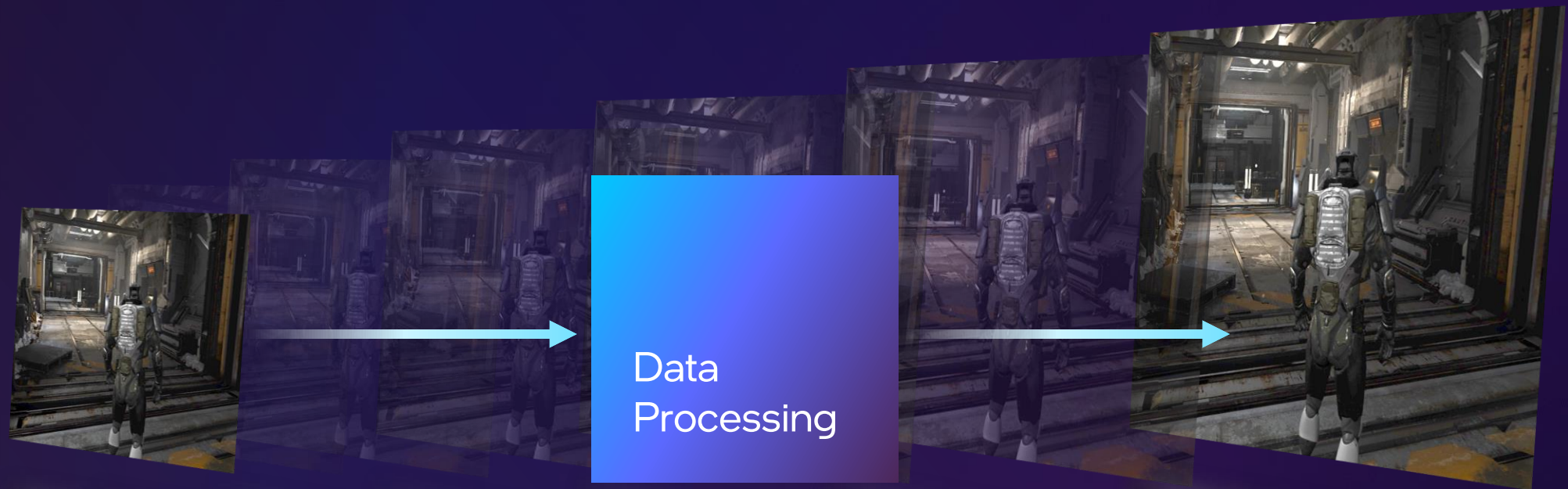
intel ARC™

Introduction to XeSS



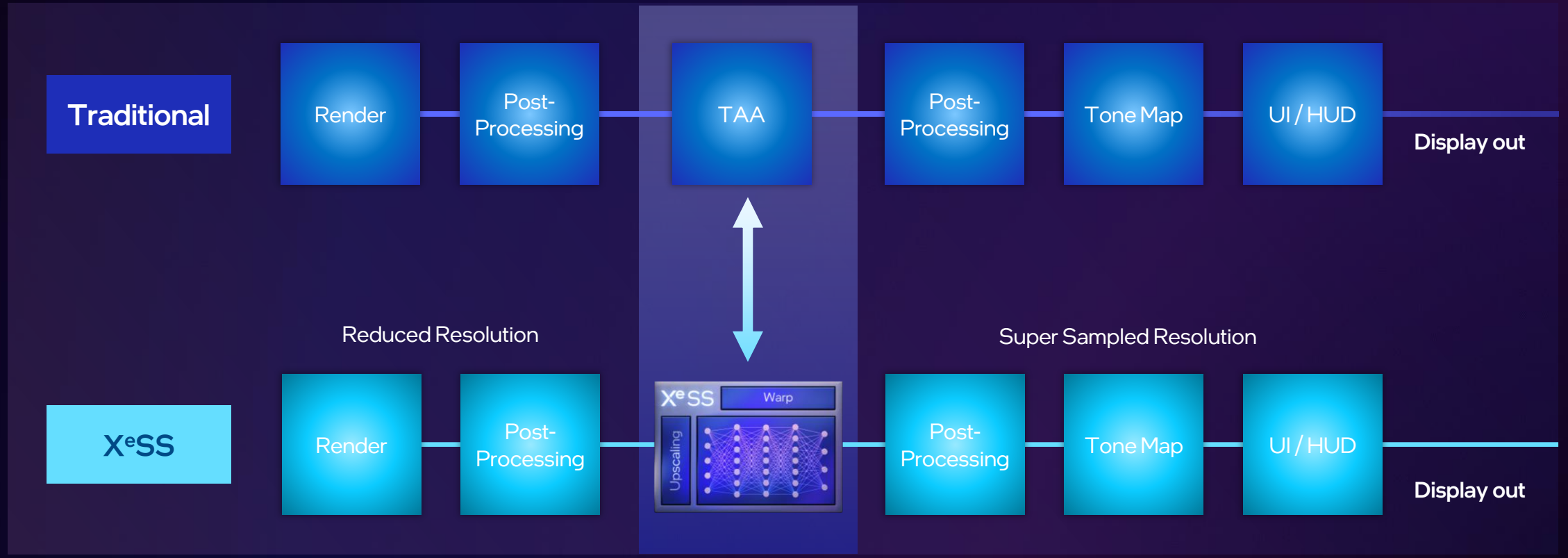
- Introduction to XeSS
- XeSS 1.1 Update
- XeSS Integration
- Upcoming: Dataset Toolkit

Better use of GPU resources



What is Xe Super Sampling?

- DL-based Temporally Amortized Super Sampling Technique
- Replaces the TAA stage in the rendering pipeline



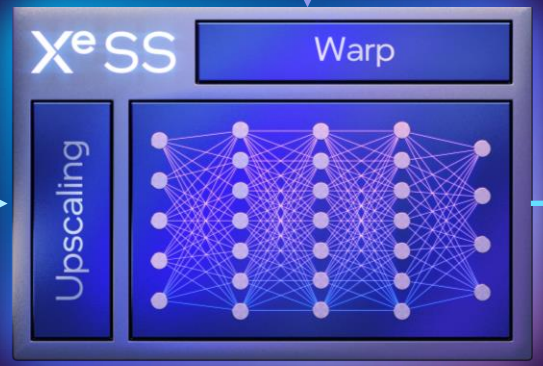
XeSS Overview

Raster, Lighting & Post-Processing

Motion Vectors

Low-Res
Frame Render

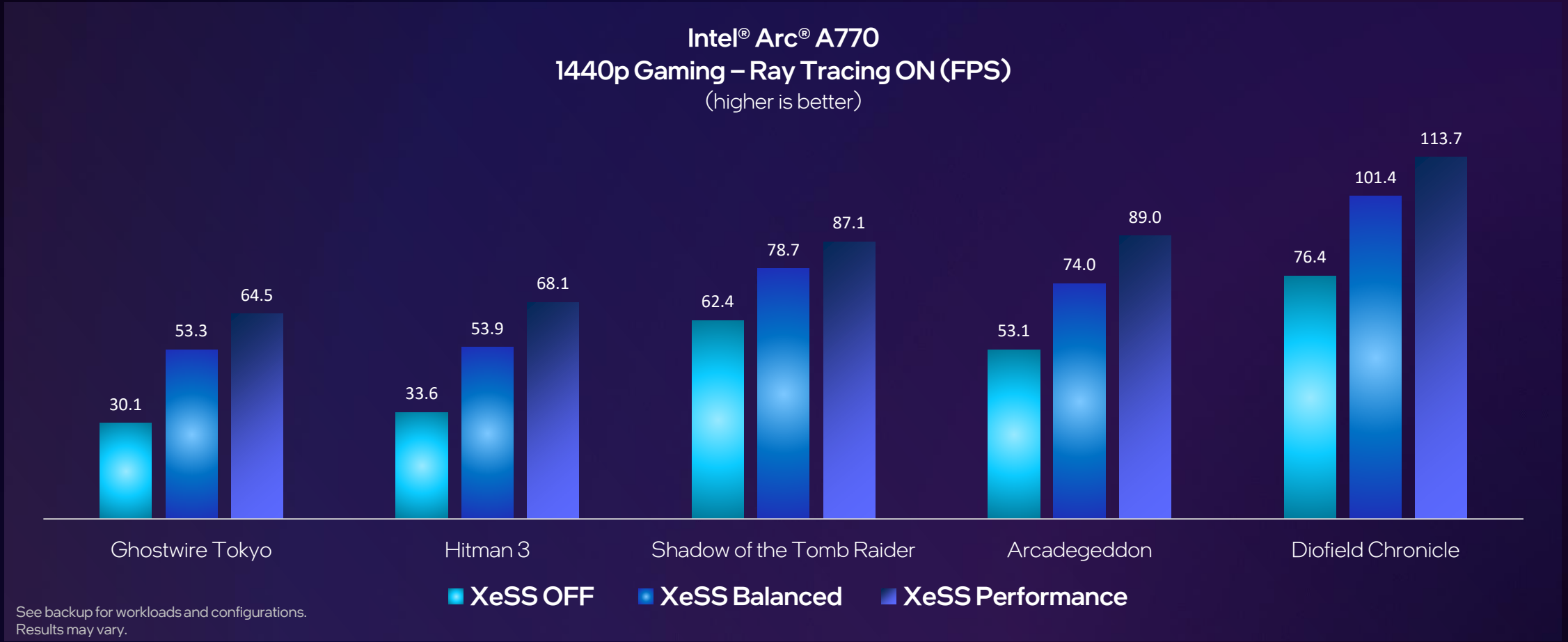
Frame History



Super Sampled
Render

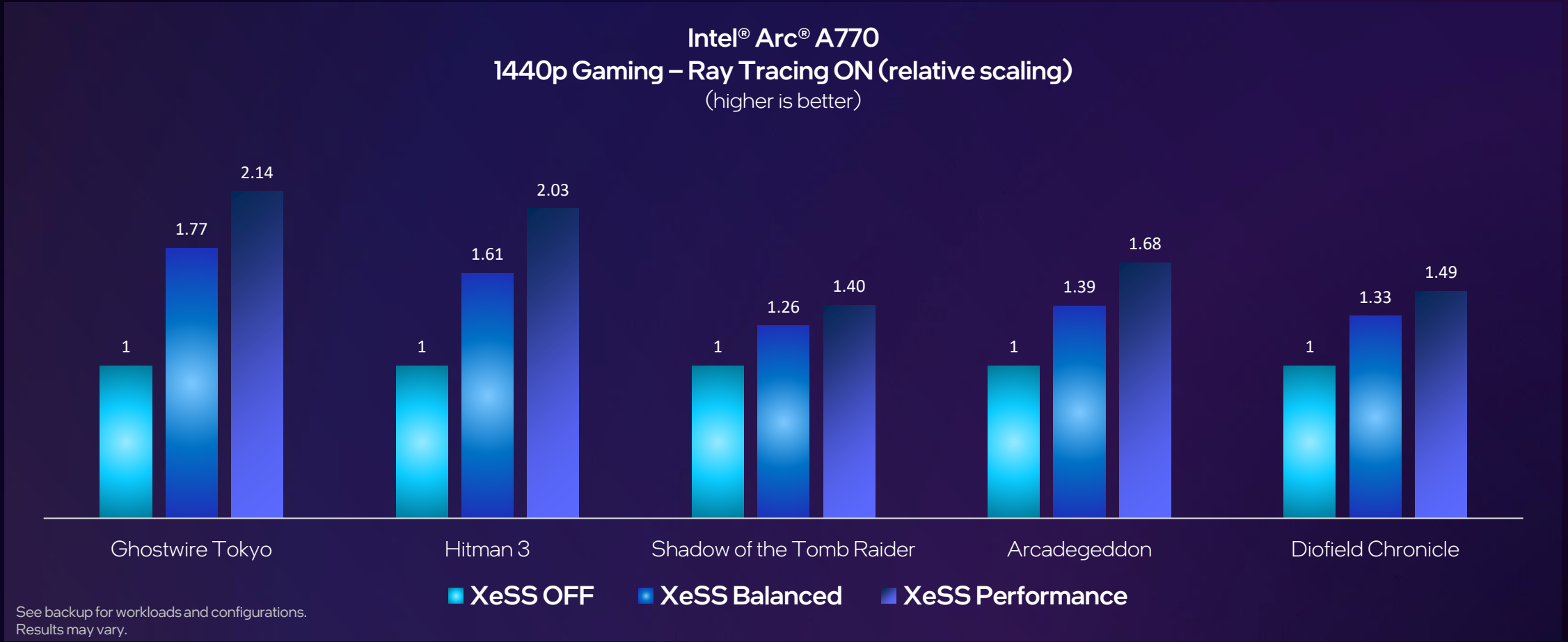
Post-Processing

High Performance on Arc A770
XeSS + Ray Tracing



See backup for workloads and configurations.
Results may vary.

High Performance on Arc A770
XeSS + Ray Tracing



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A Deeper View into XeSS Impact

XeSS for iGPUs and cross-vendor

Building XeSS for iGPUs

- Low input resolution, typically 540p for 1080p gaming
- No high-throughput matrix engine such as XMX
- Lower-throughput memory shared with CPU
- Budget <5ms to target 30-60fps at 1080p

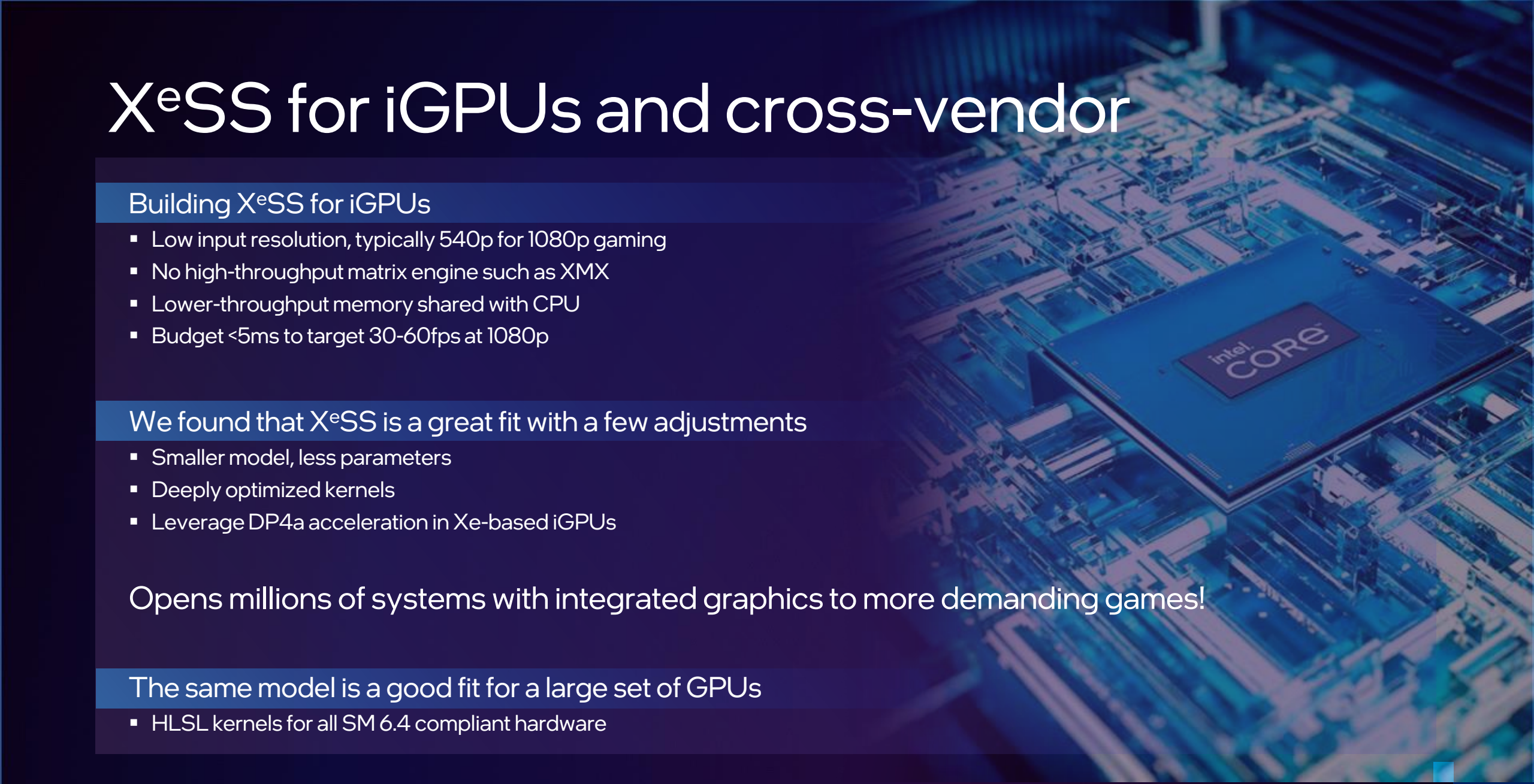
We found that XeSS is a great fit with a few adjustments

- Smaller model, less parameters
- Deeply optimized kernels
- Leverage DP4a acceleration in Xe-based iGPUs

Opens millions of systems with integrated graphics to more demanding games!

The same model is a good fit for a large set of GPUs

- HLSL kernels for all SM 6.4 compliant hardware



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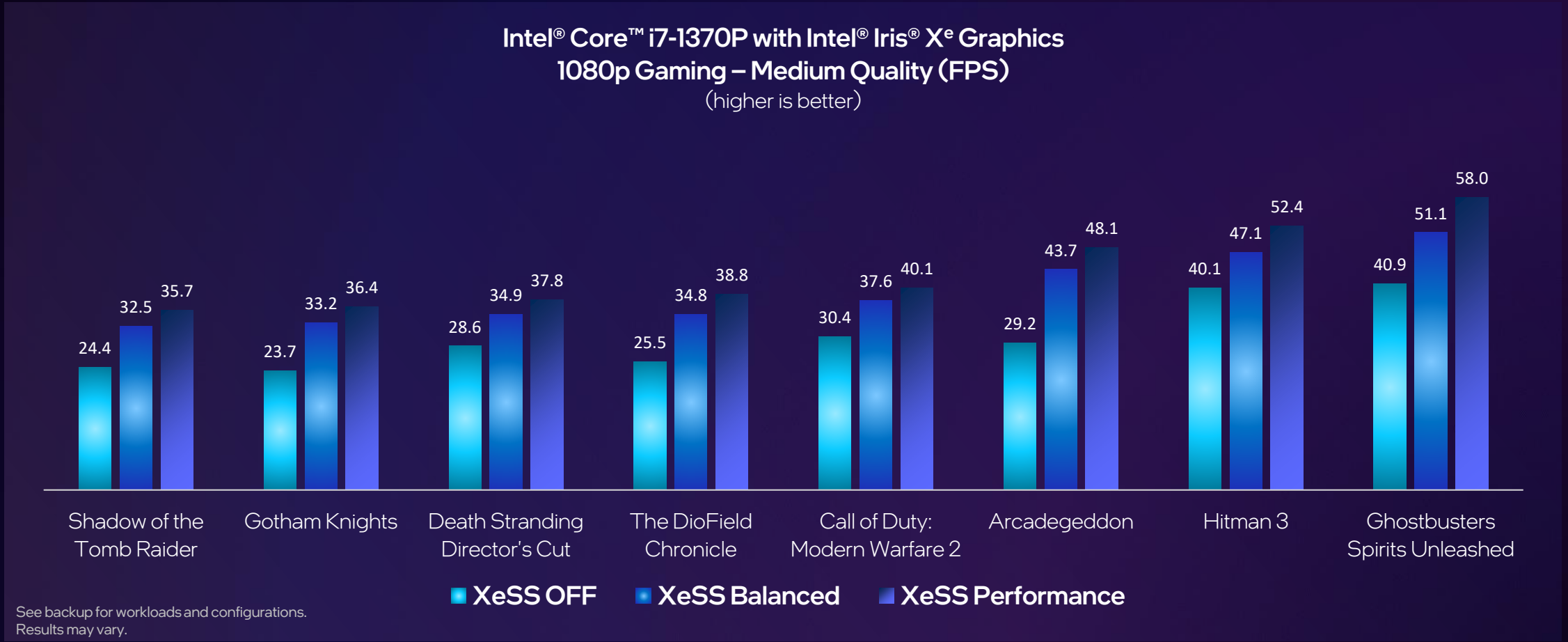
XeSS Performance on iGPU



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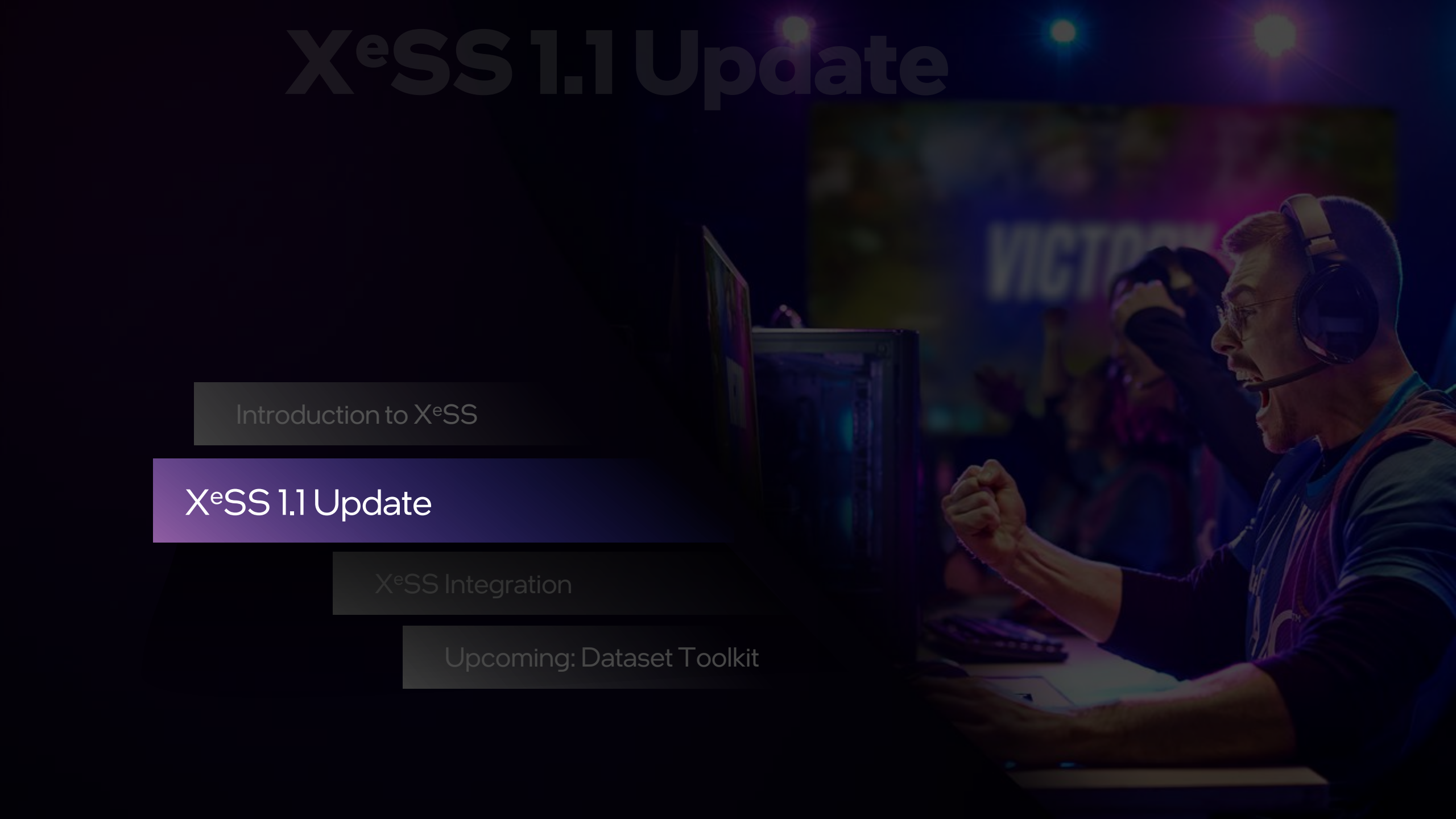
XeSS 1.1 Update



Introduction to XeSS

XeSS 1.1 Update

XeSS Integration

Upcoming: Dataset Toolkit

XeSS

Software Stack

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XeSS

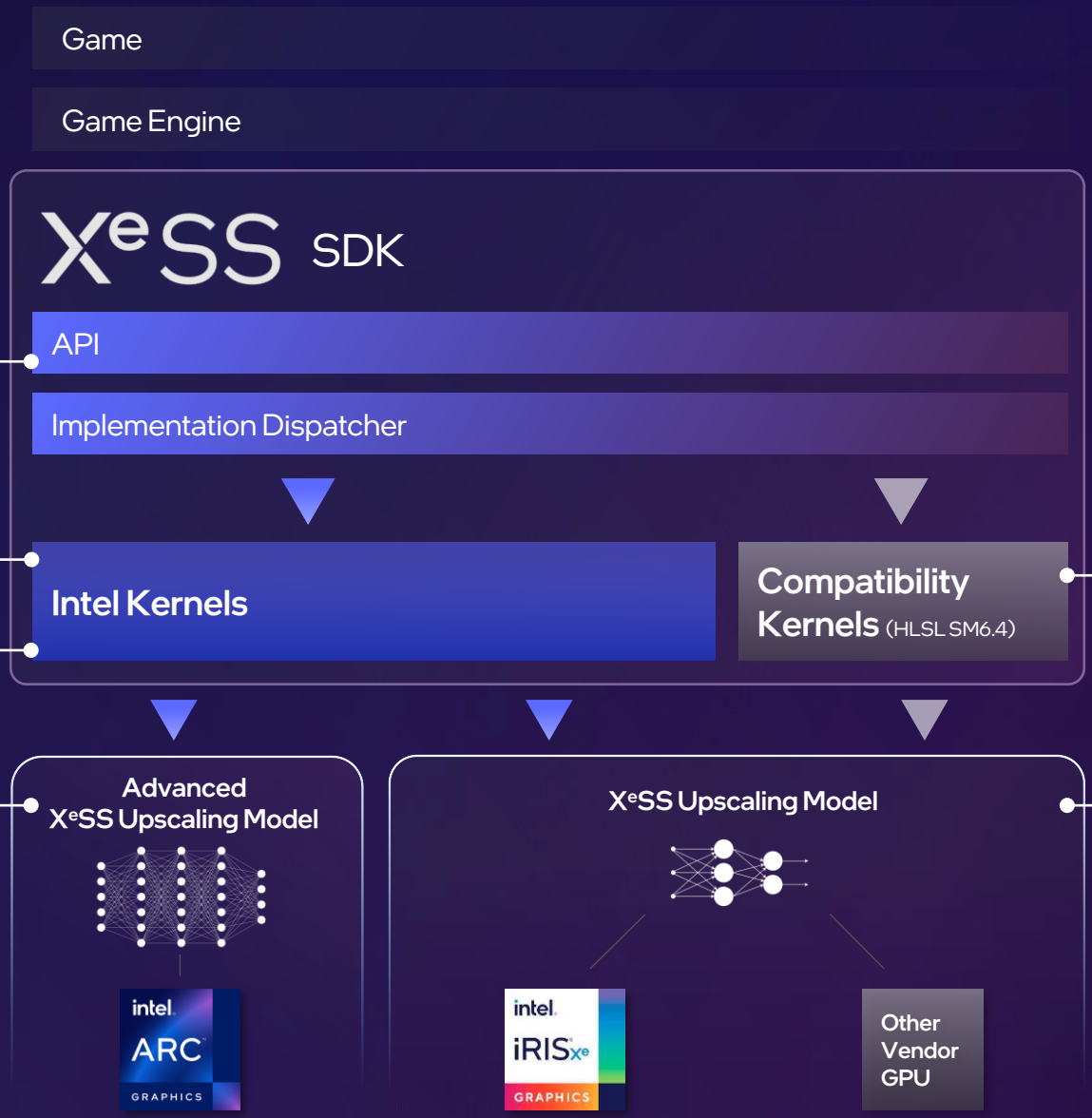
1.1 Update

Optional auto-exposure

Faster XMX kernels
- Arc A-series dGPU

Faster DP4a kernels
- TGL/ADL/RPL iGPU

New Advanced XeSS Upscaling Model
- Improved temporal stability (flicker/moire)



Faster cross-vendor kernels
- SM 6.4 compatible GPUs

New XeSS Upscaling Model
- Improved temporal stability (flicker/moire)

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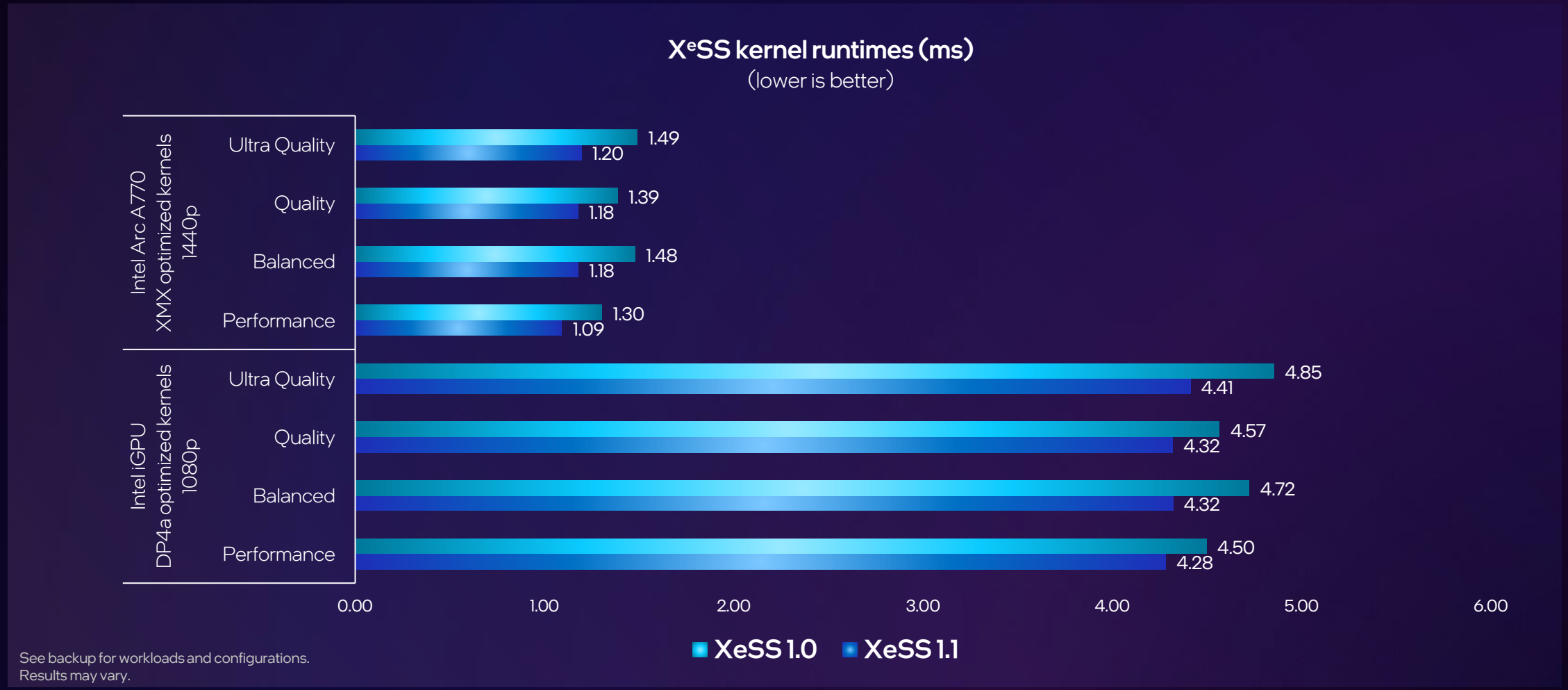
Kernel Optimization



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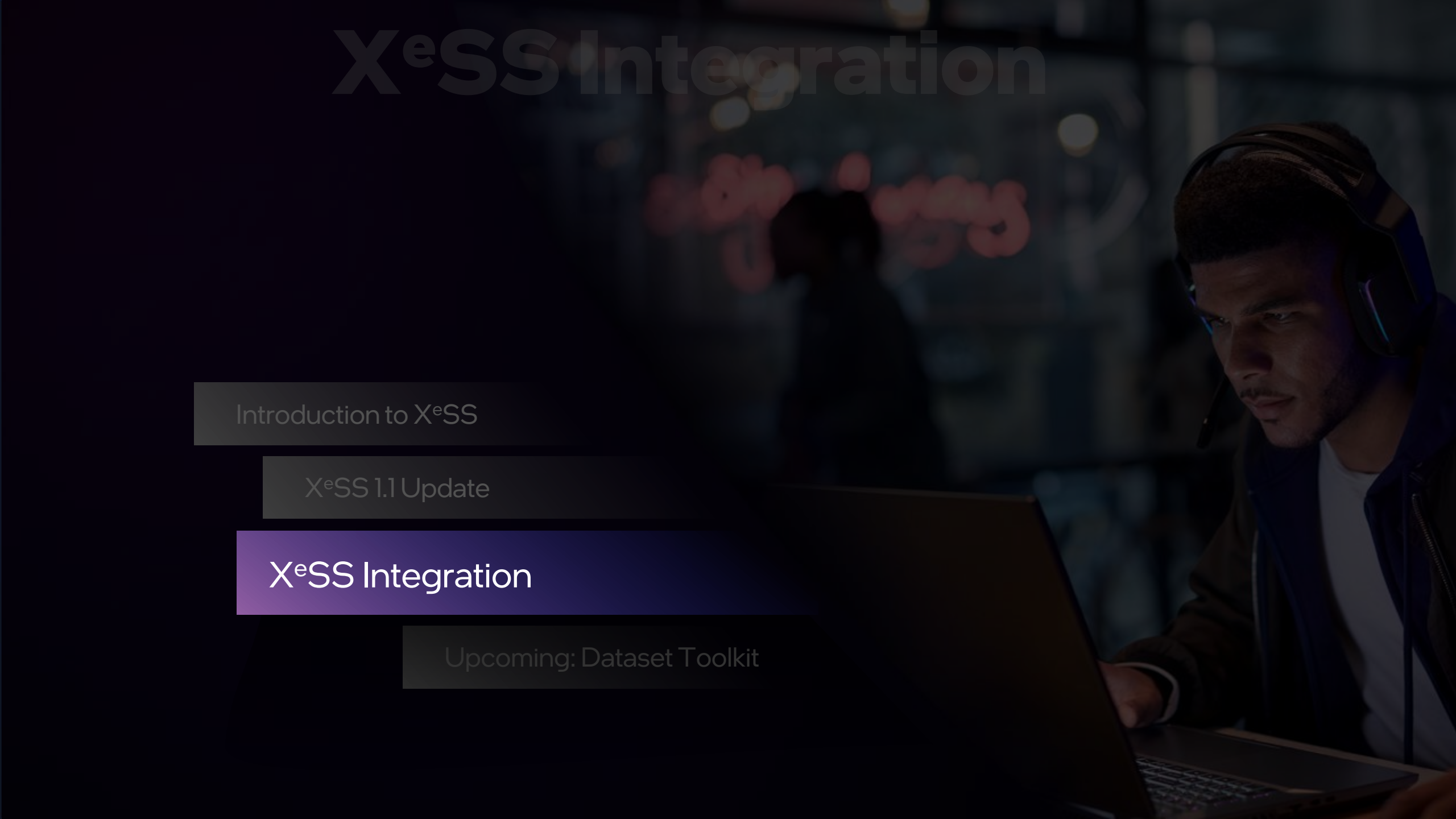
XeSS 1.0
XeSS 1.1
2x Zoom

XeSS Integration



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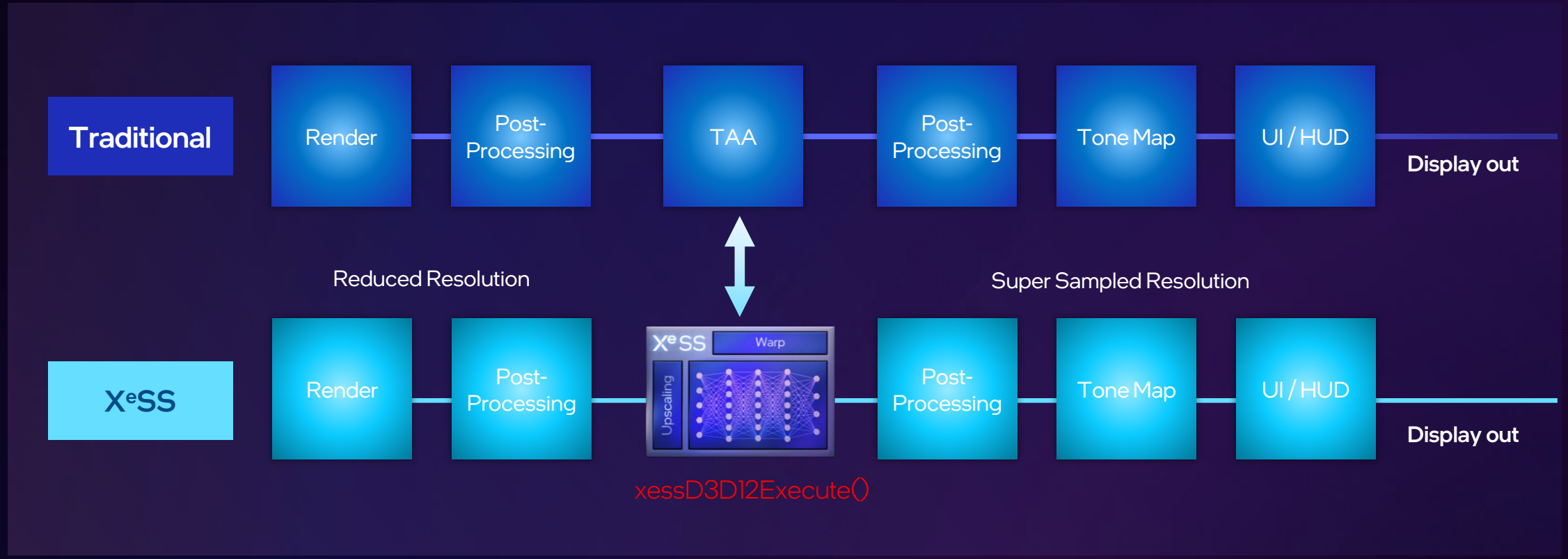
Rendering pipeline with XeSS



- Replace your TAA implementation with XeSS:
  - Record XeSS command buffer using xessD3D12Execute()
  - Run XeSS command buffer before tone mapping

API overview

Simple workflow

- Query input resolution using xessGetInputResolution()
- Create rendering pipelines
- Initialize XeSS using xessD3D12Init()
- Record XeSS command buffer using xessD3D12Execute()
- Run XeSS command buffer before tone mapping

The XeSS API automatically selects the appropriate model

- XMX-accelerated neural network on Intel ARC graphics
- DP4a-based neural network on Intel iGPU and compatible Nvidia/AMD hardware

New in XeSS 1.1 API: autoexposure init flag

XESS_INIT_FLAG_ENABLE_AUTOEXPOSURE

- Set if current frame exposure value is not available from the engine
- Reduces ghosting and flicker compared to non-exposed input
- Only applicable to HDR input
- Small performance cost

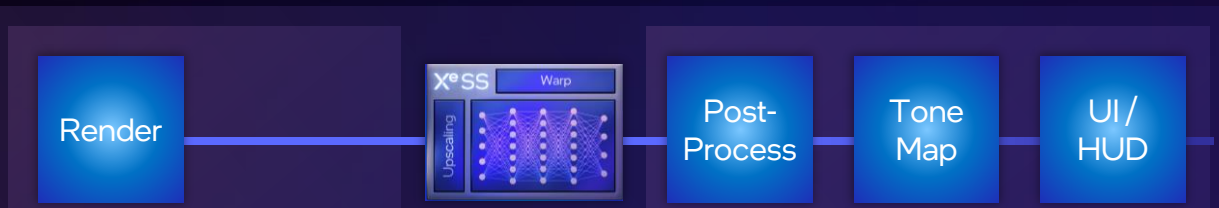
XeSS Scaling Factors

XeSS Mode	Input	Output	Scaling Factor
Performance XESS_QUALITY_SETTING_PERFORMANCE	960 x 540	1920 x 1080	2.00x
	1280 x 720	2560 x 1440	
	1920 x 1080	3840 x 2160	
Balanced XESS_QUALITY_SETTING_BALANCED	1130 x 636	1920 x 1080	1.70x
	1506 x 848	2560 x 1440	
	2259 x 1271	3840 x 2160	
Quality XESS_QUALITY_SETTING_QUALITY	1280 x 720	1920 x 1080	1.50x
	1707 x 960	2560 x 1440	
	2560 x 1440	3840 x 2160	
Ultra Quality XESS_QUALITY_SETTING_ULTRA_QUALITY	1477 x 831	1920 x 1080	1.30x
	1970 x 1108	2560 x 1440	
	2954 x 1662	3840 x 2160	

Higher Performance

Higher Quality

Post Processing Considerations



XeSS before post-processing
- Best image quality and temporal stability
- Lower performance gains

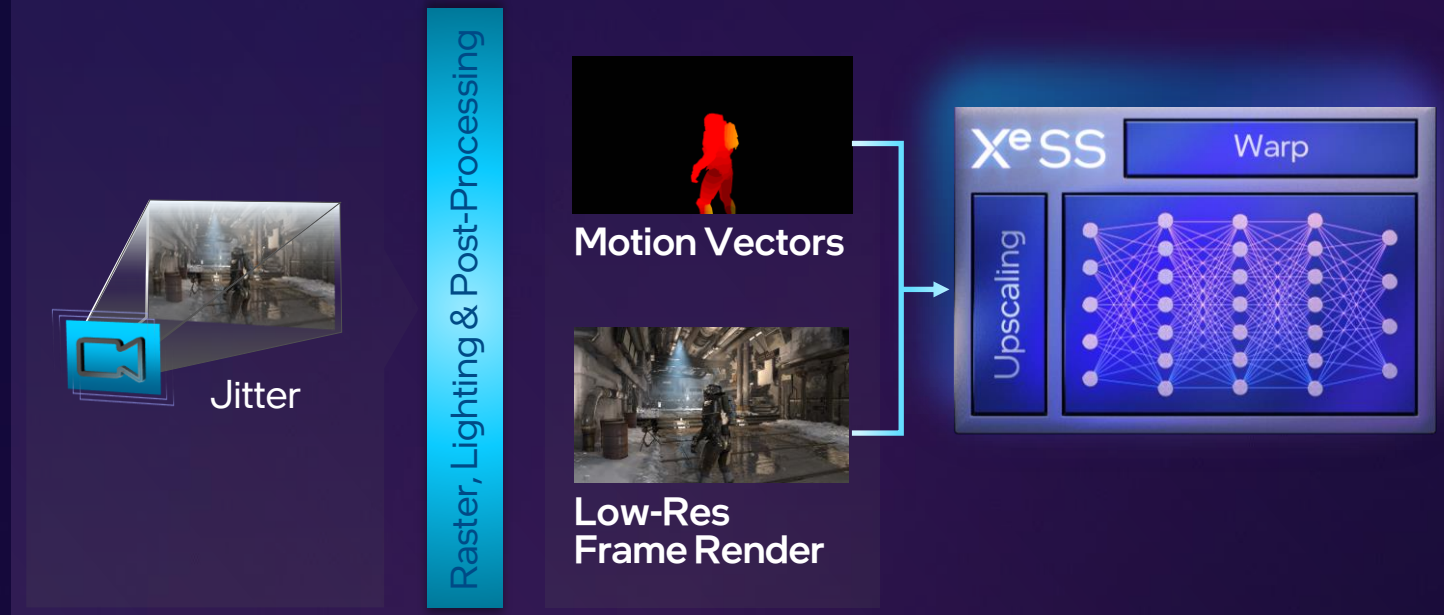
XeSS in the middle of post-processing
- Best performance/quality tradeoff in most cases
- Effects that severely disturb the input image should be implemented after XeSS: DoF, Bloom, screen-space fog, screen-space atmospherics such as godrays and volumetric fog

XeSS after post-processing
- Largest performance gains
- More visual artifacts

Inputs Summary

XeSS requires a minimum set of inputs every frame:

- Low-Resolution Frame Render
- Jitter offset
- Motion vectors



Inputs Summary

XeSS requires a minimum set of inputs every frame:

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- Jitter offset
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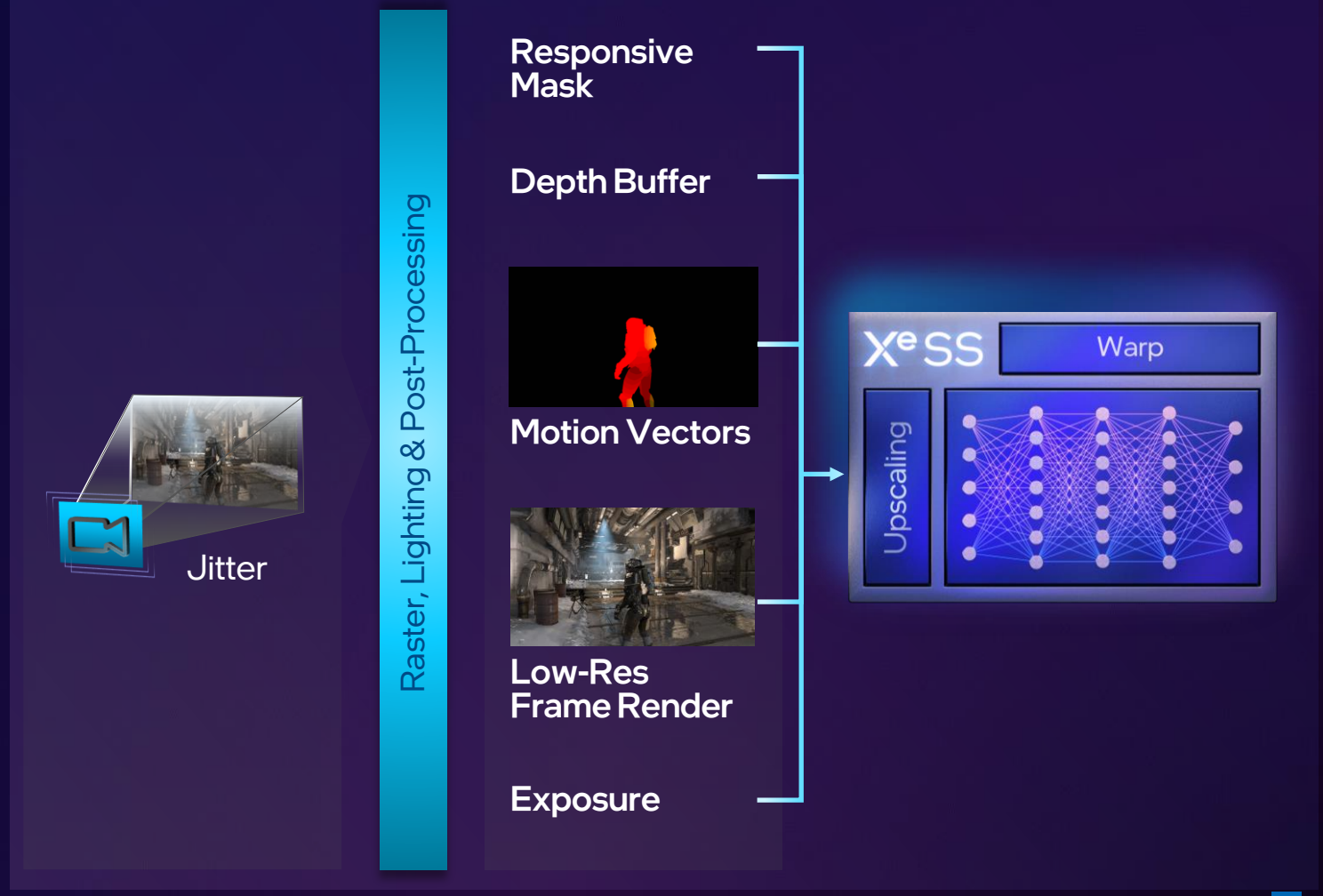
Few optional inputs:

- Exposure
- Depth Buffer
- Responsive Mask



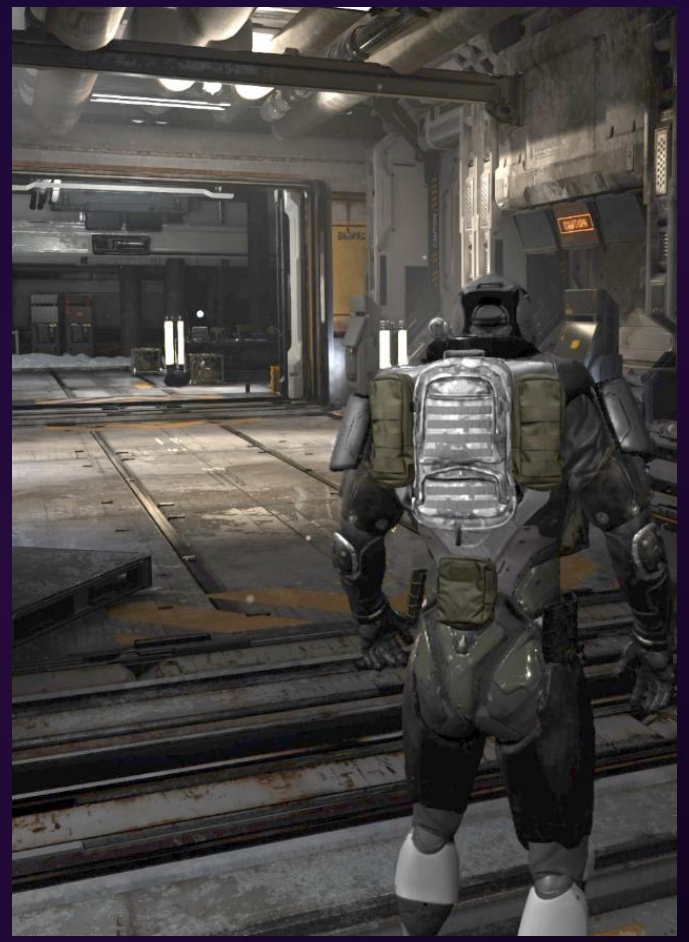
Low-Resolution Frame Render

Pass HDR input to XeSS

- XeSS applies the optimal tonemap
- Requires correct exposure
- Pass current exposure divided by pre-exposure for pre-exposed signal

LDR input is supported but not recommended

- Set exposure to “1”
- XeSS quality may decrease



Jitter

- XeSS requires a sub-pixel jitter offset (Jx,Jy) to be applied to every frame
- Jitter values are in the range [-0.5, 0.5]
- Can be applied by adding a shear transform to the camera projection matrix:

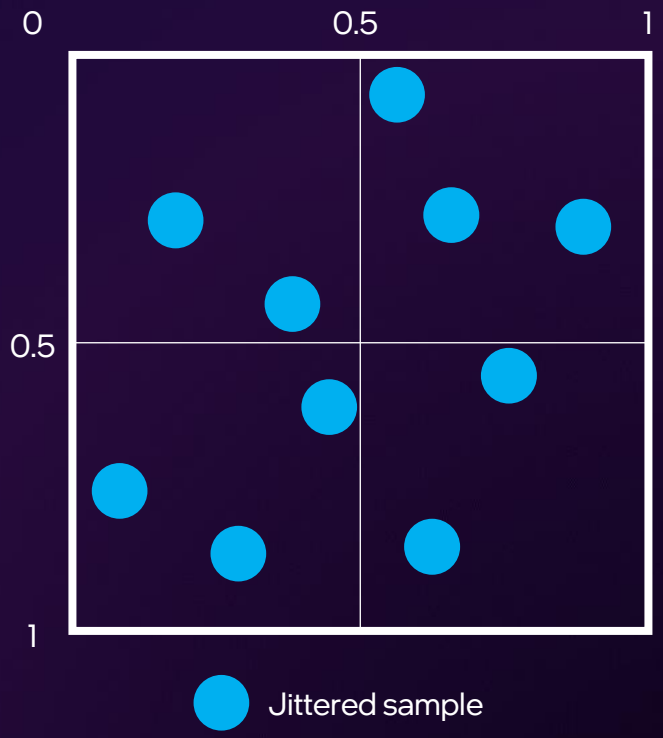
```
ProjectionMatrix.M[2][0] += Jx * 2.0f / InputWidth
ProjectionMatrix.M[2][1] -= Jy * 2.0f / InputHeight
```

Jitter sequence min required length is 32 for 2x upscale

- 64 is recommended length for better moire convergence and flicker reduction
- Choose between Halton and Blue Noise
- Blue Noise provides better spatial coverage but requires more complex implementation in engines to generate

For best quality, complex effects should be unjittered and denoised before compositing with direct illumination

- reflections, refractions,...



Motion Vectors

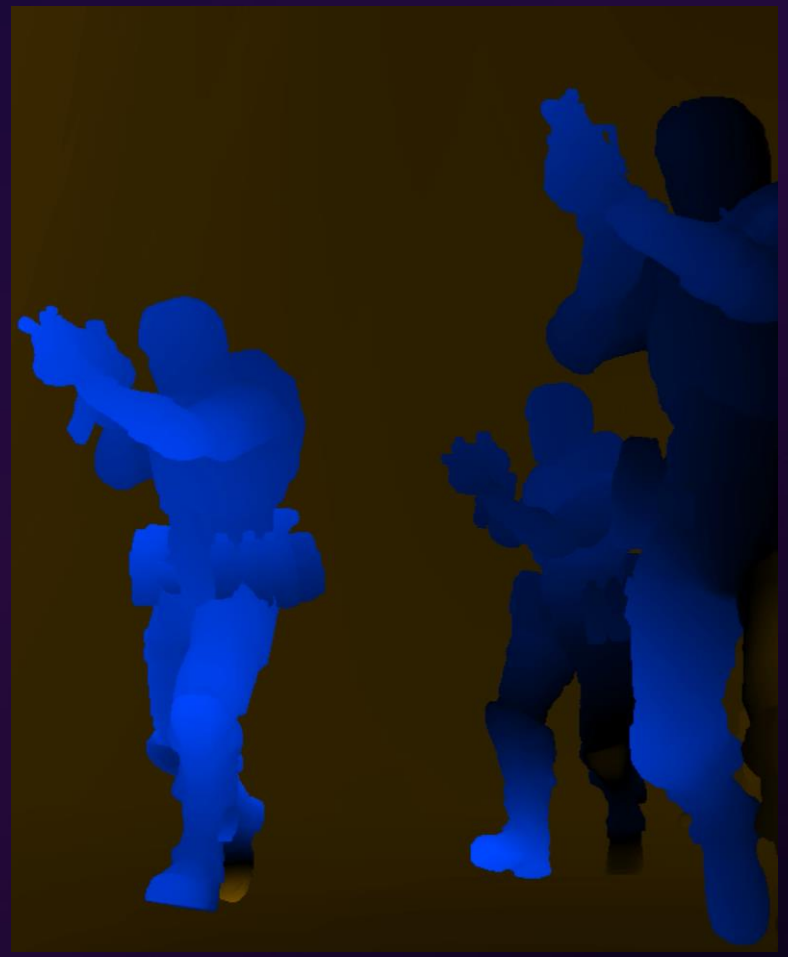
- Represents screen-space motion from the current frame to the previous frame
- Combines velocity of dynamic objects and camera movement
- XeSS accepts 2 options:

High-resolution motion vectors:

- Motion vectors must be pre-dilated
- Simple approach: take front most velocity in a small neighborhood of input pixels (e.g. 3x3)

Low-resolution motion vectors

- Requires depth
- Requires inverted/not-inverted depth flag
- XeSS will upsample and dilate it internally



Motion Vectors and Jitter Tweaks

Jittered and un-jittered motion vectors are supported

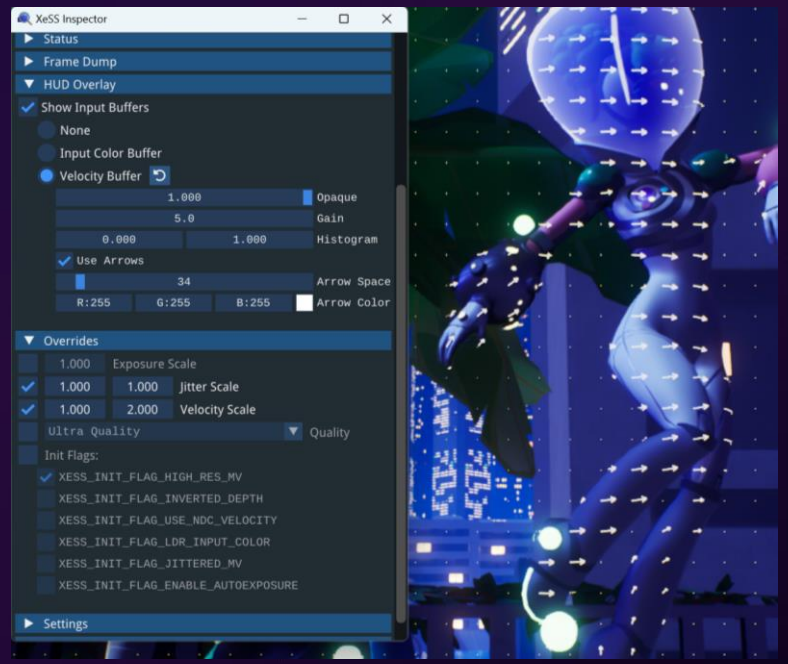
- do not forget to set XESS_INIT_FLAG_JITTERED_MV flag accordingly

Shaking XeSS output may be caused by coordinate system mismatch between what XeSS expects and what game engine provides

- Use xessSetJitterScale() and xessSetVelocityScale() to invert jitter and/or motion vectors accordingly
  - Check if that resolves the problem.
- Use a static scene to debug invalid motion vectors vs invalid jitter: set scale factor = 0 for motion vectors
  - If the problem goes away, the root cause is likely with motion vectors
  - Otherwise, the problem is with invalid jitter

We've created XeSS Inspector to help

- Let us know if you would like to get early access!



Mipmap bias

- **To preserve texture details at the target resolution, XeSS requires a mipmap bias of:**

$$log_2\left(\frac{InputWidth}{TargetWidth}\right) - x$$

- **Recommend to initially set x = 0, can be fine tuned based on title**
- **For example, a mipmap bias of -1 should be applied for 2x resolution scaling (x = 0)**

To address flickering moire patterns:

- Increase the mipmap bias (ex. set it to -0.5 instead of -1)
- This may help solve issues with dynamic moire flicker but may make textures look less detailed

To address blurry textures:

- Decrease the mipmap bias (ex. set it to -1.5 instead of -1)
- This will provide better detail, but may cause flickering moire artefacts

default mipmap bias

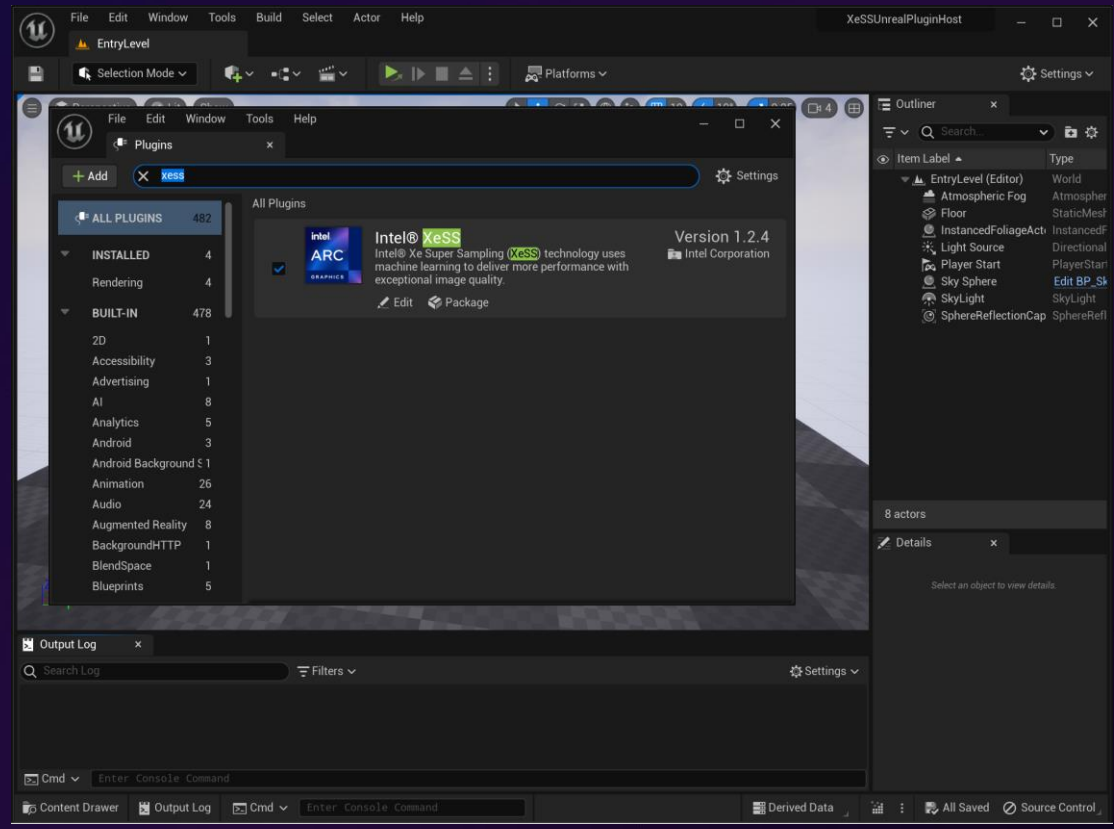
adjusted mipmap bias

Unreal Engine* XeSS Plugin

Simplifies integration of XeSS

Supports:

- Unreal Engine 4.26+
- Unreal Engine 5
- Code patch available for Unreal Engine 4.25



github.com/GameTechDev/XeSSUnrealPlugin

Upcoming: XeSS Dataset Toolkit

Introduction to XeSS

XeSS 1.1 Update

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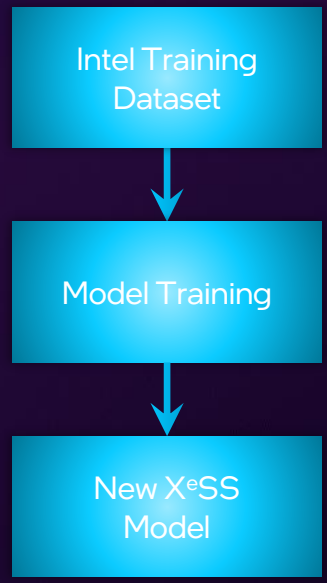
XeSS training dataset and reconstruction challenge

XeSS is trained with a dataset selected by Intel graphics experts.

If the model is presented with very unusual visuals elements, it may result in excessive flicker, moire and ghosting artifacts.

The solution: include challenging visuals in the training dataset.

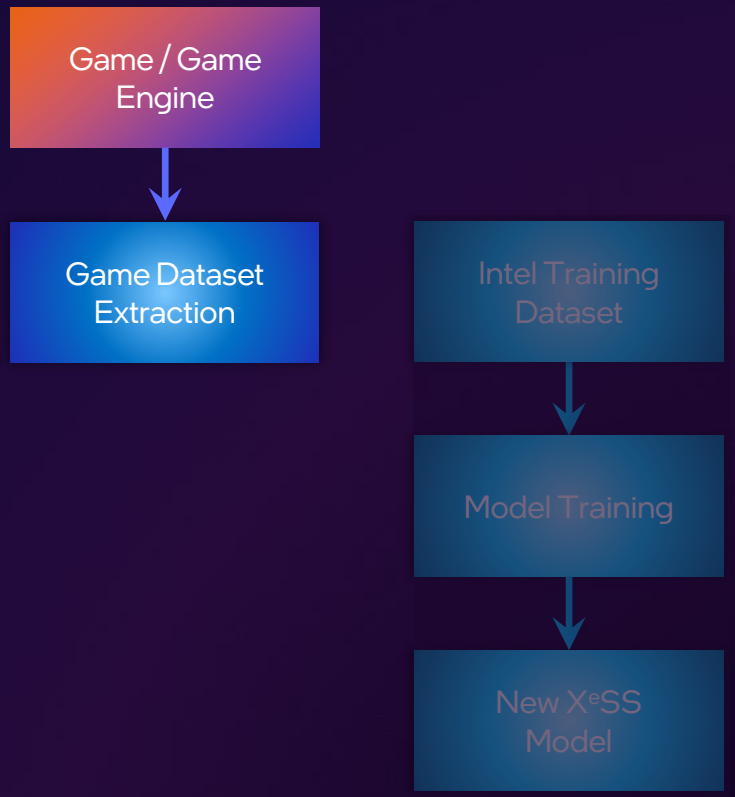
Can we simplify and accelerate the process for game developers?



Introducing the XeSS Dataset Toolkit

Dataset extraction API

- Integrates with the game engine to capture training data
- Captures:
  - Jitter offsets
  - Low-res jittered HDR color
  - Low-res depth buffer
  - Low-res motion vectors / hi-res dilated motion vectors
  - Optional parameters
- The game/engine:
  - Freezes timestamps and suspends animations, dynamic effects, etc
  - Captures jittered data over frozen scenes



Introducing the XeSS Dataset Toolkit

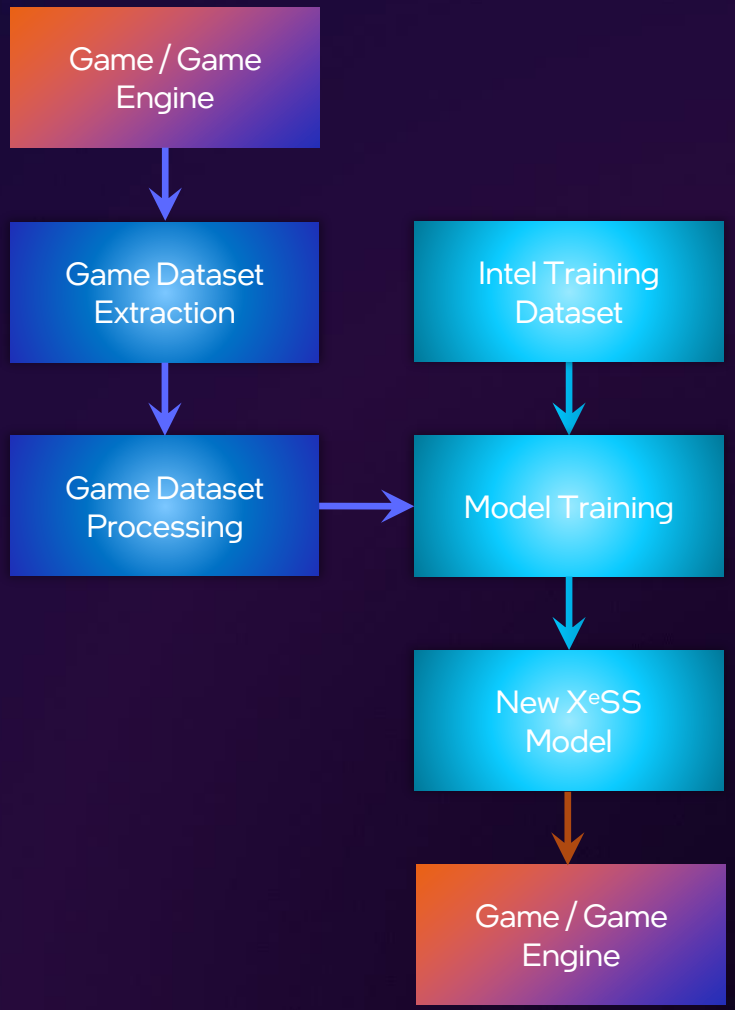
XeSS Dataset Processing Tool:

- Automatically reconstructs "ground truth" training data
- Creates a complete dataset to augment XeSS training

Intel re-trains XeSS:

- Game-derived dataset helps improve model
- Provide the updated model for integration

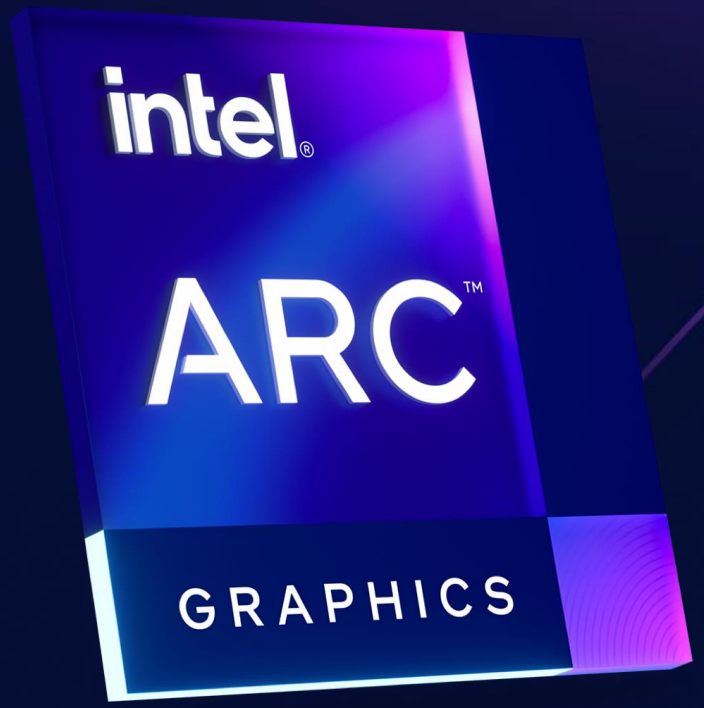
Will be available as UE4 and UE5 plugins



Summary

- High-quality AI-based super sampling
- XeSS supports dGPUs and iGPUs
- XeSS 1.1 with improved models
- XeSS Dataset Toolkit

Get XeSS today! **github.com/intel/xess**



Thank you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Workloads and Configurations

Claim	System Configuration	Measurement	Measurement Period
Intel® Core™ i7-1370P with Intel® Iris® Xe Graphics and XeSS deliver increased performance at 1080p as measured by FPS when compared to gameplay without XeSS	Graphics: Intel® Iris® Xe Graphics, Graphics Driver: 4146, System: Pre-Production RPL-P Laptop, Power Policy: Balanced, Processor: Intel® Core™ i7-1370P, Memory: 32GB LPDDR4-4800, Storage: Samsung MZVL21T0HCLR-00B00 (1TB), OS: Windows 11 Version 22621.1265	All games tested at 1080p using medium settings. All FPS (frames per second) scores are either measured with PresentMon or in-game benchmark. All gameplay has a documented workload running the same replay or game scenario across all configurations and test runs. Game workloads that support this claim are Call of Duty: Modern Warfare 2, Hitman 3, Shadow of Tomb Raider, The DioField Chronicle, Gotham Knights, Ghostbusters Spirits Unleashed, Death Stranding Director's Cut and Arcadegeddon.	March 1-10, 2023
Updated kernels in the XeSS 1.1 API show runtimes improvement when compared to XeSS 1.0 API kernels.	Graphics: Intel® Iris® Xe Graphics, Graphics Driver: 4146, System: Pre-Production RPL-P Laptop, Power Policy: Balanced, Processor: Intel® Core™ i7-1370P, Memory: 32GB LPDDR4-4800, Storage: Samsung MZVL21T0HCLR-00B00 (1TB), OS: Windows 11 Version 22621.1265 Graphics: Intel® Arc® A770 16GB Graphics, Graphics Driver: 4146, MotherboardASUS ROG MAXIMUS Z790 Hero, Processor: Intel® Core i9-13900K, Memory: 32GB (2x16GB) DDR5 5600MHz , Storage: Corsair MP600 Pro XT 4TB NVMe , OS: Windows 11 Version 22621.1265	Intel internal XeSS kernel runtimes testing tool. Performance reported as milliseconds.	March 8-10, 2023

Workloads and Configurations

Claim	System Configuration	Measurement	Measurement Period
Intel® Arc™ A770 with XeSS delivers increased ray tracing performance at 1440p as measured by FPS when compared to gameplay without XeSS	Graphics: Intel® Arc™ A770 16GB Graphics, Graphics Driver: Engineering Driver 3262, Processor: Intel® Core™ i9-12900K, Asus ROG MAXIMUS Z690 Hero, BIOS: 1601, Memory: 32GB (2x16GB) DDR5 @ 4800MHz, Storage: Corsair MP600 Pro XT 4TB NVMe, OS: Windows 11 Version 22000.795	All games tested at 1440p and 1080p using highest possible settings, except turned off motion blur and screen effects for Shadow of the Tomb Raider. Chose highest preset, then manually increased individual settings to maximum. Ray tracing options set to maximum on all games. XeSS Performance and Balanced Mode tested on all titles. Game workloads that support this claim are Arcadegeddon, The DioField Chronicle, Ghostwire Tokyo, Hitman 3, and Shadow of the Tomb Raider	August 5-8, 2022