The Evolution of Variable Rate Shading In Games

Marissa du Bois

Senior Graphics Engineer

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VRS IN GAMES & ENGINES

VRS In Games & Engines

VALAR in World of Warcraft

Integrating XeSS & VALAR

Improving Visual Quality

VRS Tier 1 & 2 On Intel® GPUs

Variable Rate Shading Tier 1

Intel® 10th Gen Processor Graphics (code named Ice Lake)	Introduced in 2019	Set Shading Rates Per Draw Call
1x1, 1x2, 2x1, 2x2 2x4, 4x2, and 4x4	DirectX 12 API: RSSetShadingRate	

iGFX to dGFX

intel ARC GRAPHICS

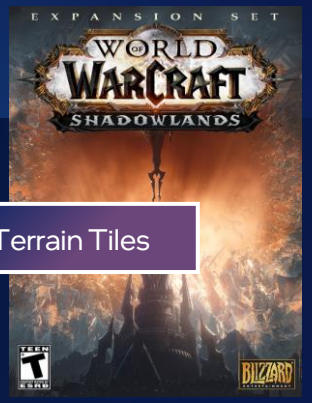
Variable Rate Shading Tier 2

Intel® Arc Graphics A-series (code named Alchemist)	Introduced in 2022	Intel's First Mainstream Discrete GPU
Image Based & Per-Prim VRS	DirectX 12 API: RSSetShadingRateImage	

intel ARC

Titles Enabled With VRS Tier 1 & Tier 2

VRS Tier 1



Terrain Tiles

Blizzard Entertainment®
2020

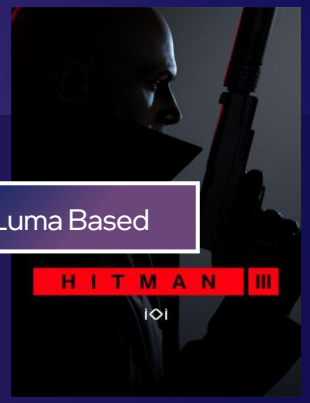
Pre-Pass

CAPCOM®
2021

Particles

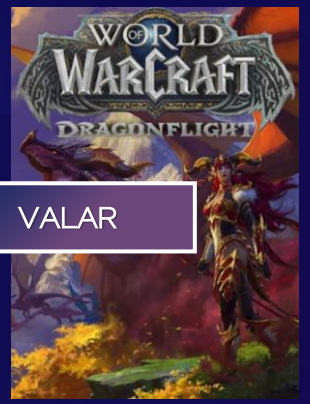
GIANTS Software
2022

VRS Tier 2



Luma Based

IO Interactive
2021



VALAR

Blizzard Entertainment®
2022

VRS Tier 1 – Per-Material

Relaxed Mode Plus

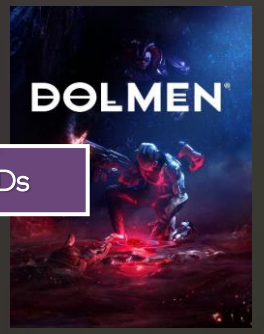
Per-Pass

Per-Material

Tripwire Interactive
2021

UNREAL ENGINE

VRS LODs



Massive Work Studio
2022

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VRS Content Published By Intel

Resource	URL	Author	Publisher	Published
Getting Started With VRS Tier 1	https://www.intel.com/content/www/us/en/developer/articles/guide/getting-started-with-variable-rate-shading-on-intel-processor-graphics.html	Adam Lake, Laura Reznikov & Marissa du Bois	Intel	2019
Using Variable Rate Shading to improve the User Experience	https://software.intel.com/en-us/videos/use-variable-rate-shading-vrs-to-improve-the-user-experience-in-real-time-game-engines	Adam Lake, Filip Strugar, Kelly Gawne, Trapper Mcferron	Intel	2019
VRS Tier 1 With Chivalry 2 (GDC 2020)	https://www.youtube.com/watch?v=d-qEvmVcg8I	Marissa du Bois & John Gibson	Intel	2020
VRS Tier 1 Usage Guide With Unreal Engine 4	https://www.intel.com/content/www/us/en/developer/articles/guide/variable-rate-shading-tier-1-usage-guide.html	Marissa du Bois & Jeff Rous	Intel	2020
Velocity And Luminance Adaptive Rasterization (VRS Tier 2)	https://www.intel.com/content/www/us/en/developer/articles/technical/velocity-luminance-adaptive-rasterization-vrs-tier.html	Marissa du Bois, Adam Lake, Meghan Weicht, Aria Kraft	Intel	2022
Velocity And Luminance Adaptive Rasterization (GDC 2022)	https://www.youtube.com/watch?v=T48dW9nvuvI	Adam Lake, Marissa du Bois	Intel	2022

VRS TIER 2 WITH VALAR

VRS In Games & Engines

VRS Tier 2 With VALAR

VALAR in World of Warcraft

Integrating XeSS & VALAR

Improving Visual Quality

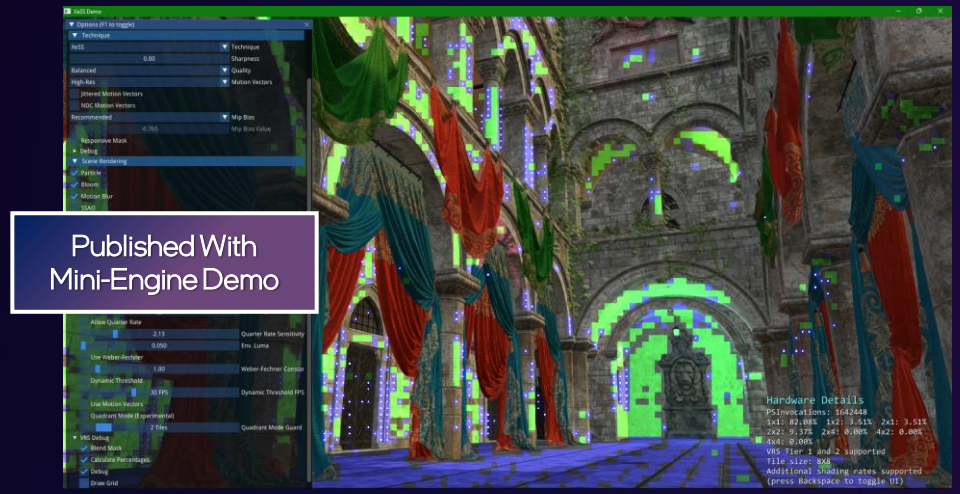
Velocity & Luminance Adaptive Rasterization

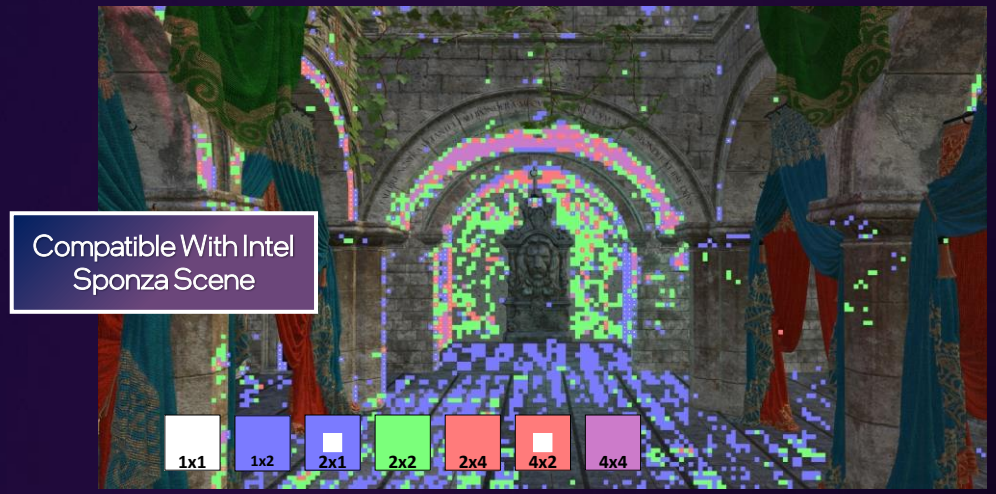
Background

- Whitepaper Published By Intel® in 2022
- Mini-Engine Demo Released on GitHub in 2022
- Based on Adaptive Shading by Lei Yang, 2019
- Approximates “Perceptually Lossless” Output
- Weber-Fechner Contrast Laws
- Luminance Mean-Squared-Error (MSE)
- Just-Noticeable-Difference (JND) Algorithm

Adjustable Input Parameters

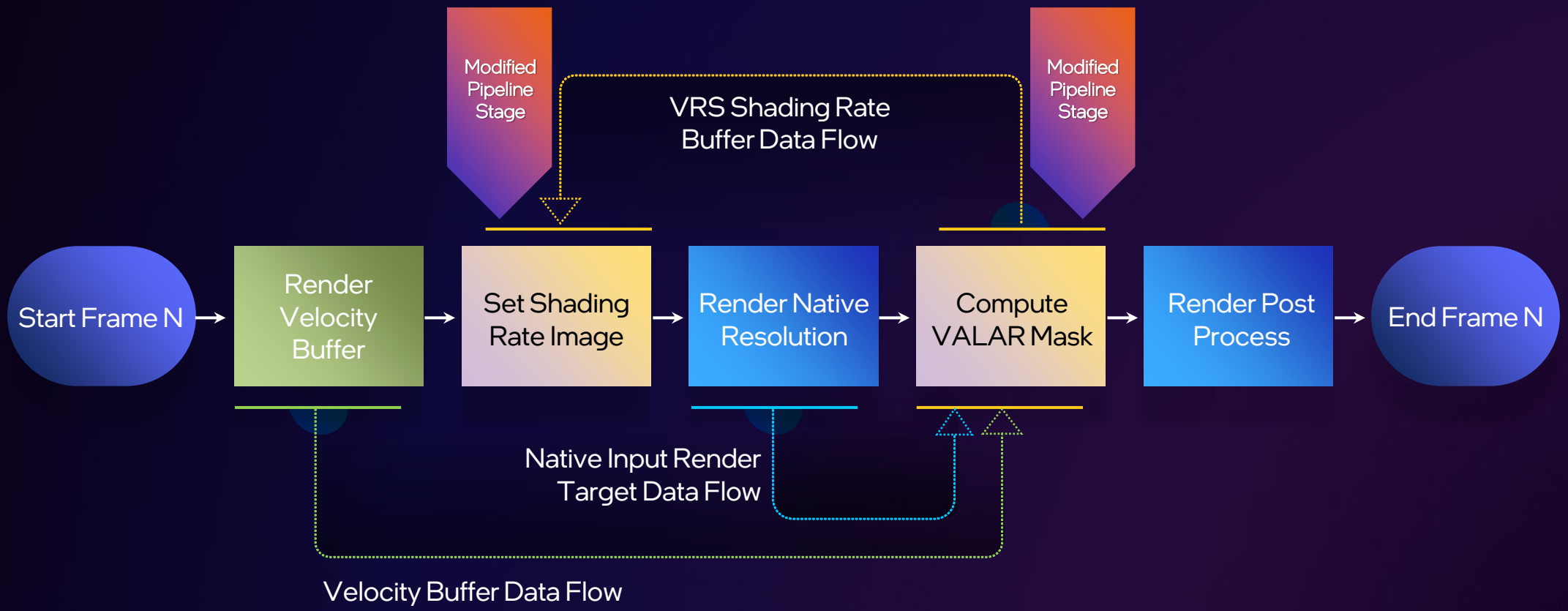
- Sensitivity Threshold (T)
- Environment Luminance (E)
- Quarter Rate Shading Modifier (K)
- Weber-Fechner Mode (C)
- Motion-Vector Mode





https://www.intel.com/content/www/us/en/developer/articles/technical/velocity-luminance-adaptive-rasterization-vrs-tier.html

VALAR Rendering Pipeline



Tile Based Luminance

Convert RGB To Luminance

$$L_p = R \cdot 0.212671 + G \cdot 0.715160 + B \cdot 0.072169$$

Sum The Tile Luminance

$$L_t = \sum L_p$$

Average The Tile Luminance

$$\bar{L}_t = \frac{L_t}{N}$$

Linear RGB Input

Screen Space Luma

Mean-Squared-Error

Sum X & Y Luma Differences Per Tile

$$\Delta_x = \sum \left| \frac{L_x - L_{x-1}}{2} \right|$$

$$\Delta_y = \sum \left| \frac{L_y - L_{y-1}}{2} \right|$$

Approximate Mode Use Weber-Fechner Mode For Tunable Precision

Average X & Y Luma Differences

$$\bar{\Delta}_x = \frac{\Delta_x}{N}$$

$$\bar{\Delta}_y = \frac{\Delta_y}{N}$$

Compute Mean Squared Error (MSE)

$$\varepsilon_x = \sqrt{\bar{\Delta}_x}$$

$$\varepsilon_y = \sqrt{\bar{\Delta}_y}$$

Used in the **Just-Noticeable-Difference** Evaluation

8x8 Luma Tiles

Average Tile Luma

Just-Noticeable-Difference

Compute The Just-Noticeable-Difference

$$J = T \cdot (\bar{L}_t + E)$$

T & E Configured by User

Branchless JND & MSE Evaluation

$$R_x = R_2 \cdot \neg\big((\varepsilon_x \geq J) \vee (\varepsilon_x < J)\big) + R_4 \cdot (\varepsilon_x < J)$$

$$R_y = R_2 \cdot \neg\big((\varepsilon_y \geq J) \vee (\varepsilon_y < J)\big) + R_4 \cdot (\varepsilon_y < J)$$

Branchless Logic Evaluates to 0 or 1

Terms Are Mutually Exclusive

Combine X & Y Shading Rates

$$R = R_x \ll 2 \mid R_y$$

X & Y Shading Rate

Final Shading Rate

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Motion Vectors [Optional]

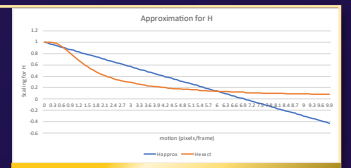
Find The Minimum Tile Velocity

$$V_t = min(Vp, Vt)$$

Half & Quarter Rate Velocity Modifiers [Yang, 2019]

$$V_h = \left(\frac{1}{1 + (1.05 \cdot V_t)^{3.10}}\right)^{0.35}$$

$$V_q = 2.13 \cdot \left(\frac{1}{1 + (0.55 \cdot V_t)^{2.14}}\right)^{0.49}$$



Substitute With Linear Approximation

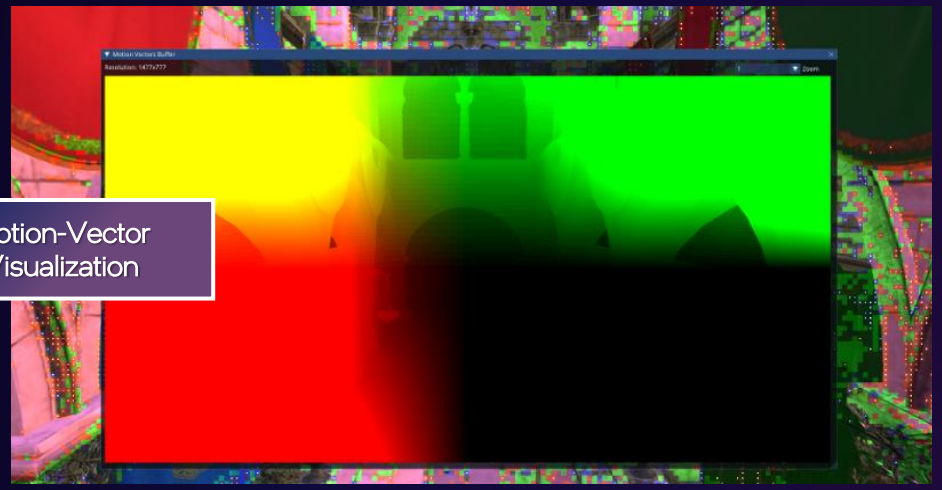
Combine X & Y Shading Rates

$$R_x = R_2 \cdot \neg\left((V_h \cdot \varepsilon_x \geq J) \vee (V_q \cdot \varepsilon_x < J)\right) + R_4 \cdot (V_q \cdot \varepsilon_x < J)$$

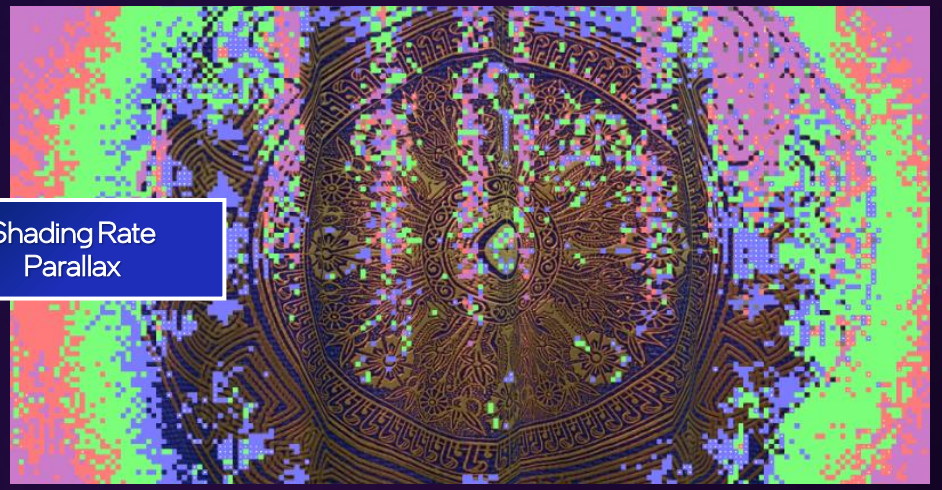
$$R_y = R_2 \cdot \neg\left((V_h \cdot \varepsilon_y \geq J) \vee (V_q \cdot \varepsilon_y < J)\right) + R_4 \cdot (V_q \cdot \varepsilon_y < J)$$

MSE Modified By Velocity

Precompute Repeated Expressions

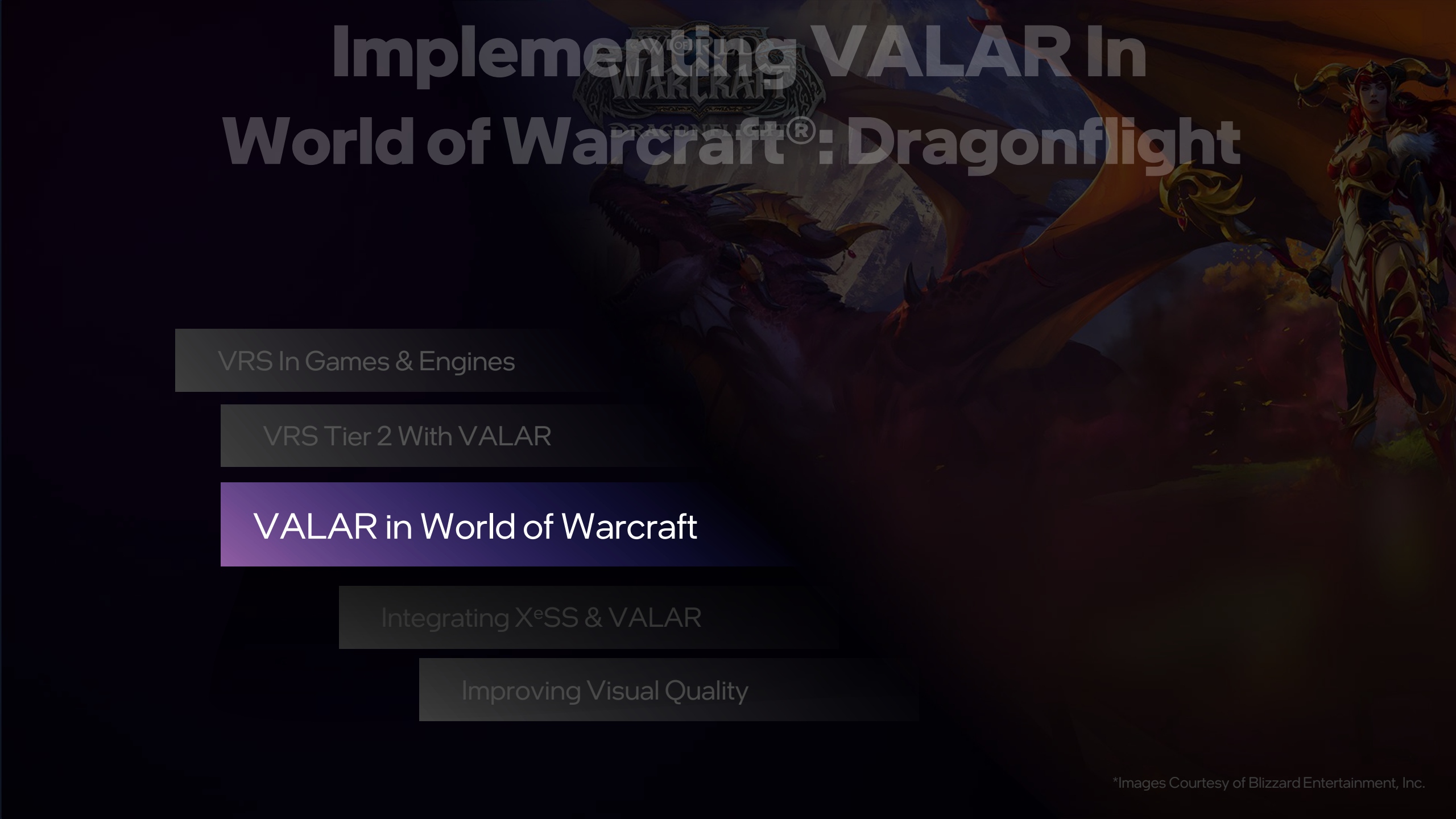


Motion-Vector Visualization



Shading Rate Parallax

Implementing VALAR In World of Warcraft®: Dragonflight



- VRS In Games & Engines
- VRS Tier 2 With VALAR
- **VALAR in World of Warcraft**
- Integrating XeSS & VALAR
- Improving Visual Quality

*Images Courtesy of Blizzard Entertainment, Inc.

VALAR In World of Warcraft

Background

- Disabled, Standard, and Aggressive Modes
- NPCs & Player Models Rendered at 1x1
- Opaque Geometry Uses Screen Space Shading
- Doodads Rendered With Screen Space Shading

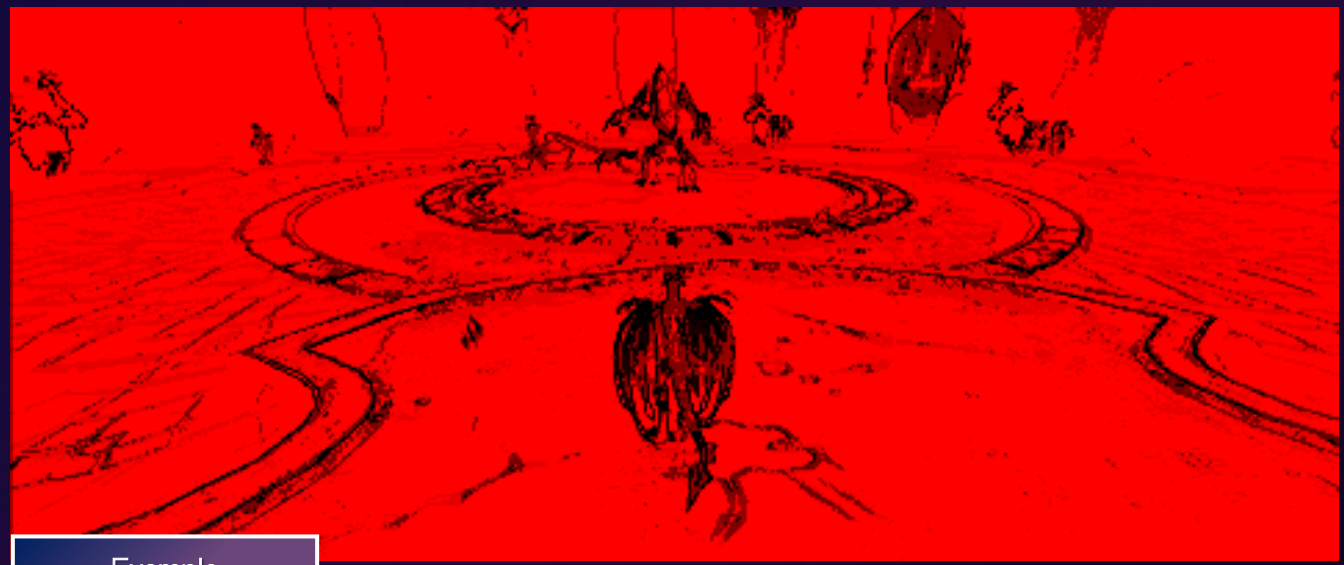
Default Configuration

- Standard Sensitivity: 0.31
- Aggressive Sensitivity: 0.50
- Quarter Rate Shading Modifier: 2.13
- Environment Luminance: 0.05
- Motion Vector Mode: Disabled
- Weber-Fechner Mode: Disabled

Considerations

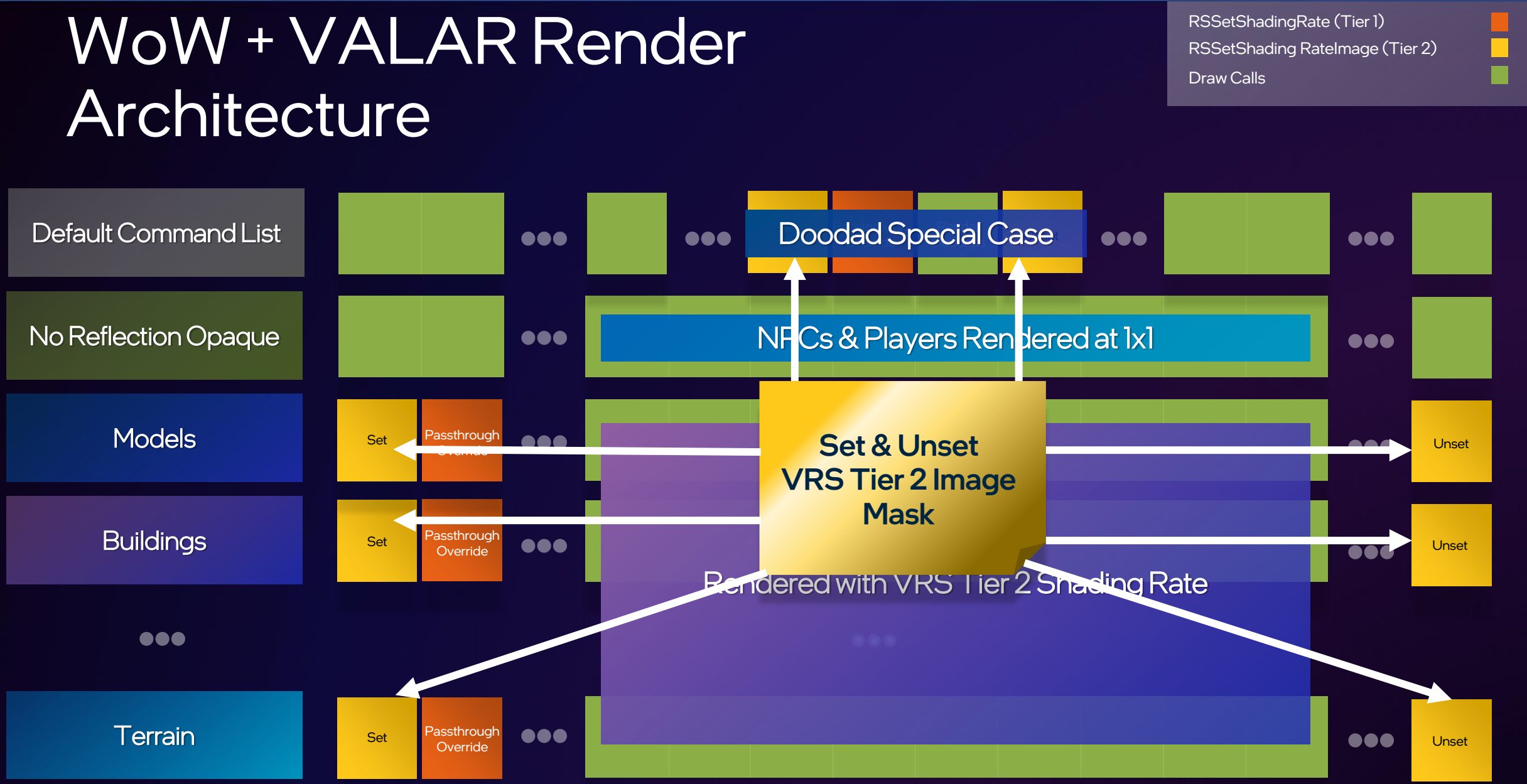
- Uses Multiple Command Lists
- Doesn't Support Motion Vectors
- Manual Alpha-Test Visual Corruption

VRS Tier 2 Settings

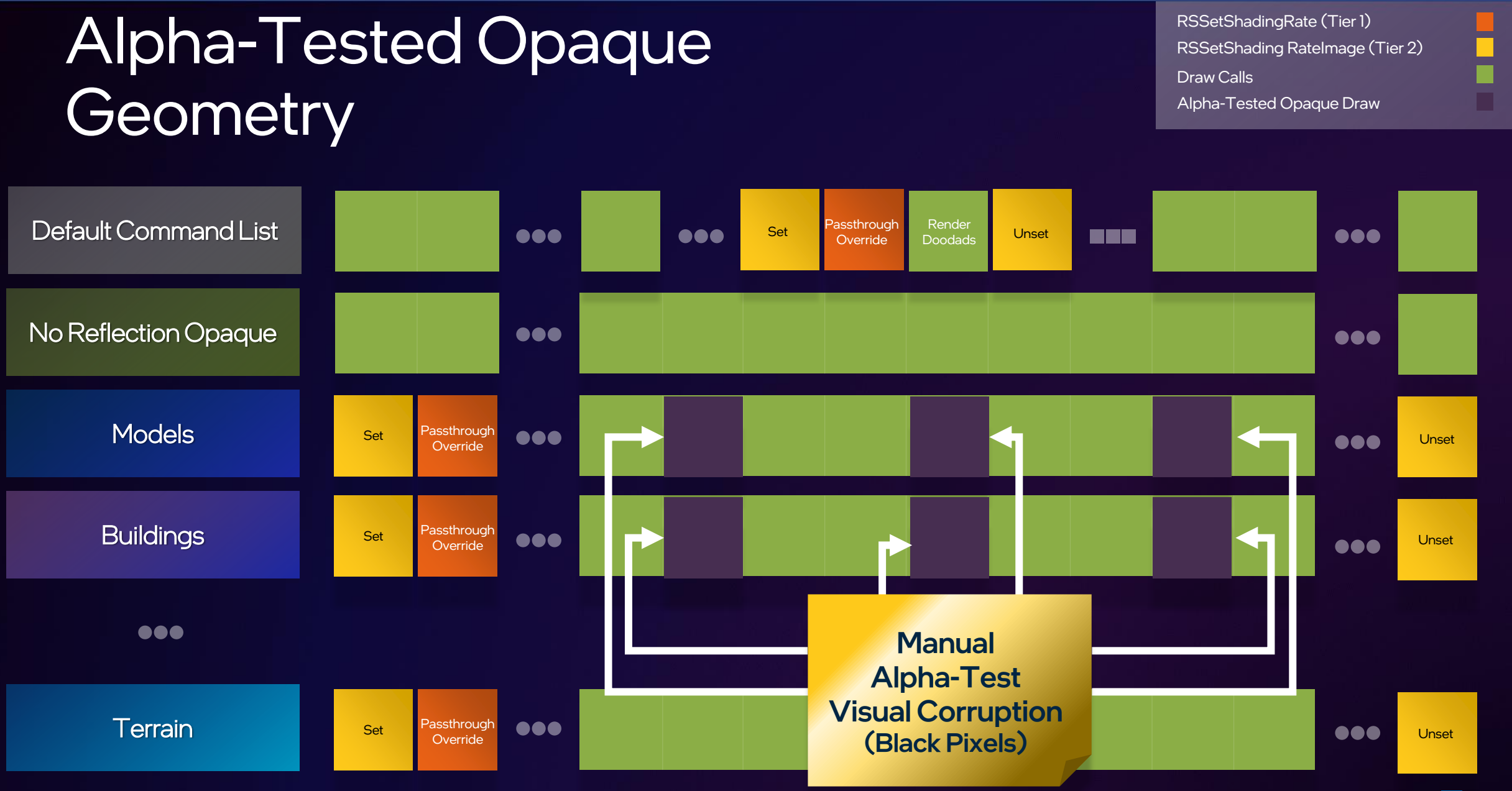


Example VRS Buffer

WoW + VALAR Render Architecture



Alpha-Tested Opaque Geometry

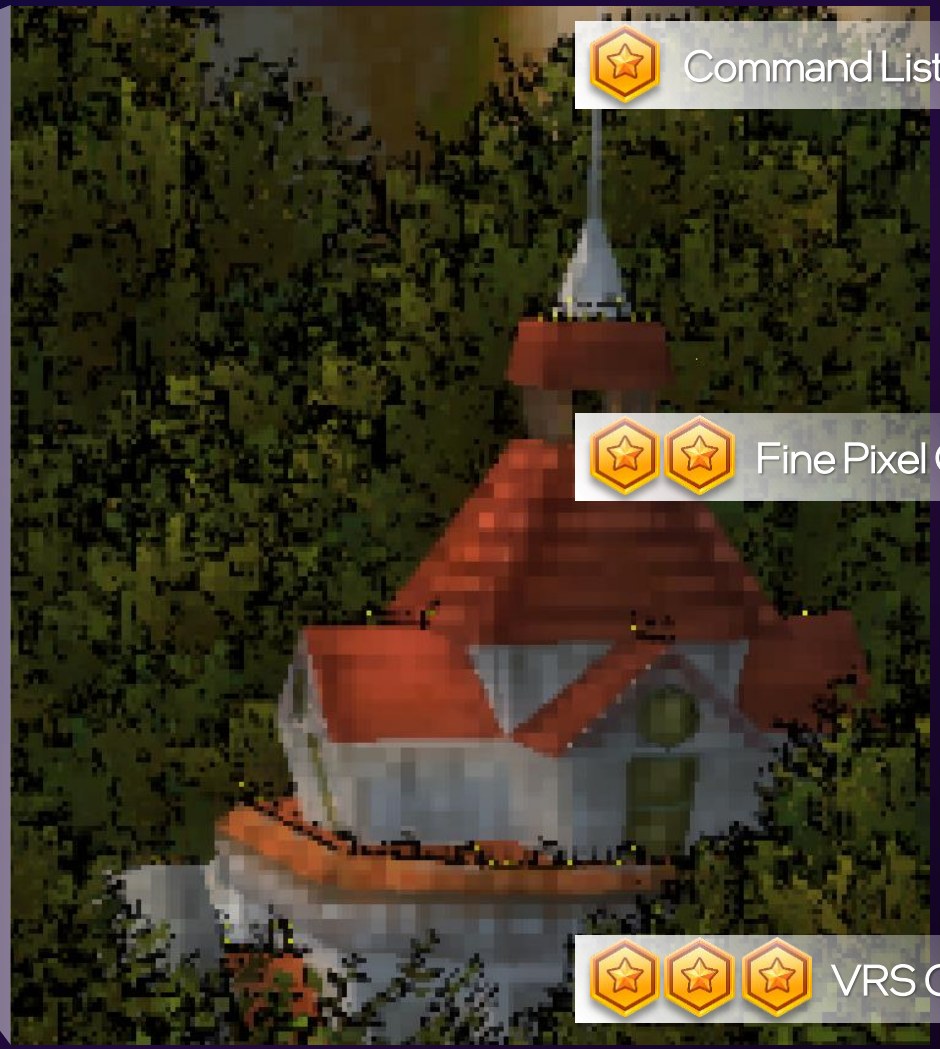


Manual Alpha-Test Visual Corruption

- Black Pixels
- Edges of Foliage
- Models & Buildings
- Manual Alpha-Test
- Uses Discard

*Images Courtesy of Blizzard Entertainment, Inc.

Manual Alpha Test –
Visual Corruption Example*



Manual Alpha Test – Cropped & Zoomed **400%***

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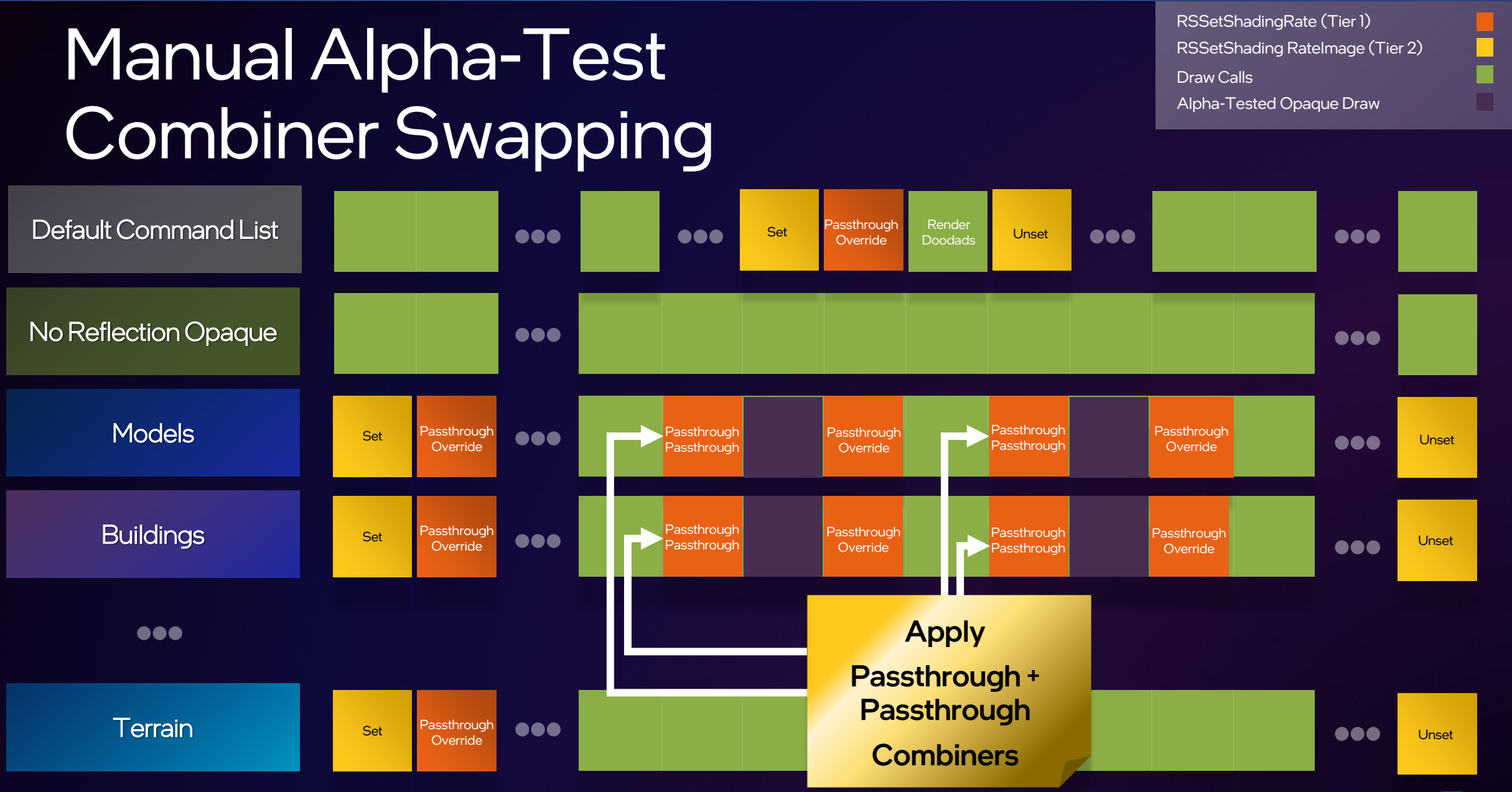
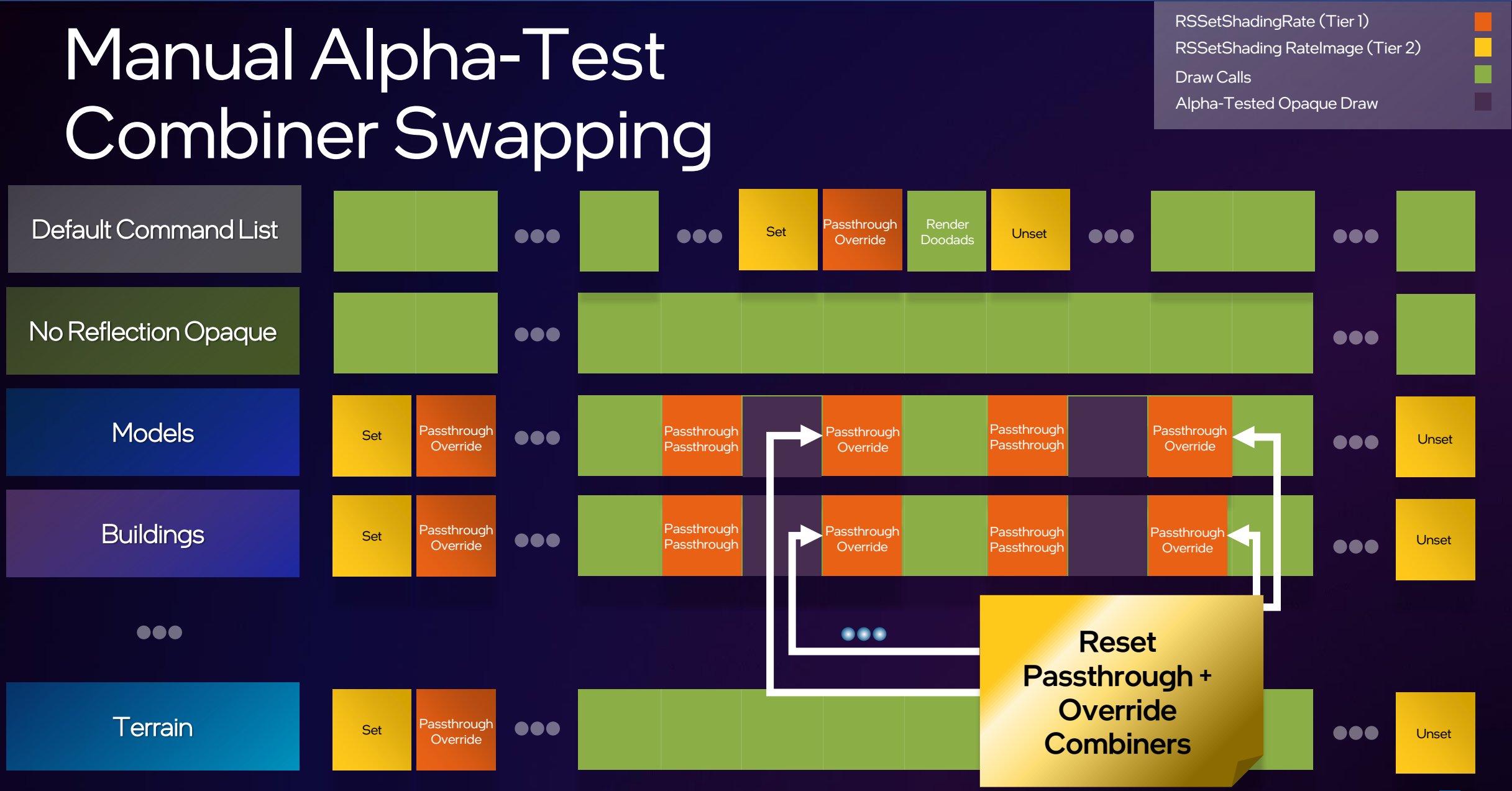
Manual Alpha-Test Combiner Swapping



Manual Alpha-Test Combiner Swapping



Using VRS Combiners

Combiners Can Be Applied

- Per-Draw (PS)
- Per-Provoking Vertex (VS)
- Per-Primitive (GS)
- Image Based (CS/CPU)

Used in WoW

Used in WoW

Types of VRS Combiners

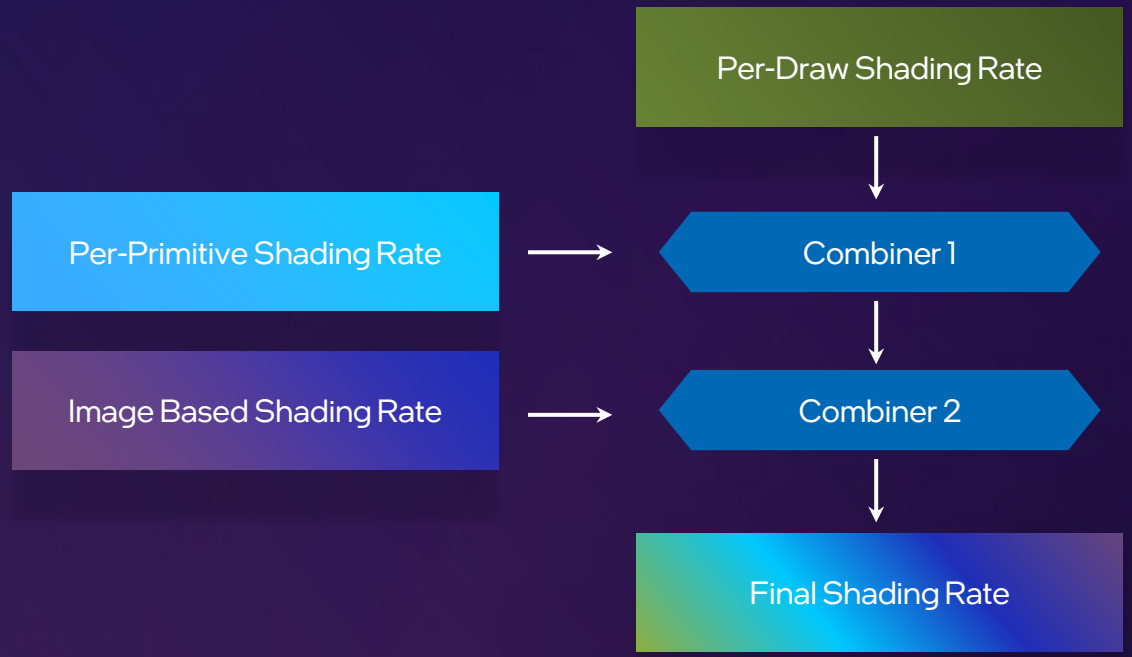
- Passthrough
- Override
- Min
- Max
- Sum

Check Hardware Features

DirectX 12 Combiner API

- void RSSetShadingRate(D3D12_SHADING_RATE baseShadingRate, const D3D12_SHADING_RATE_COMBINER *combiners);

VRS Combiner Flow



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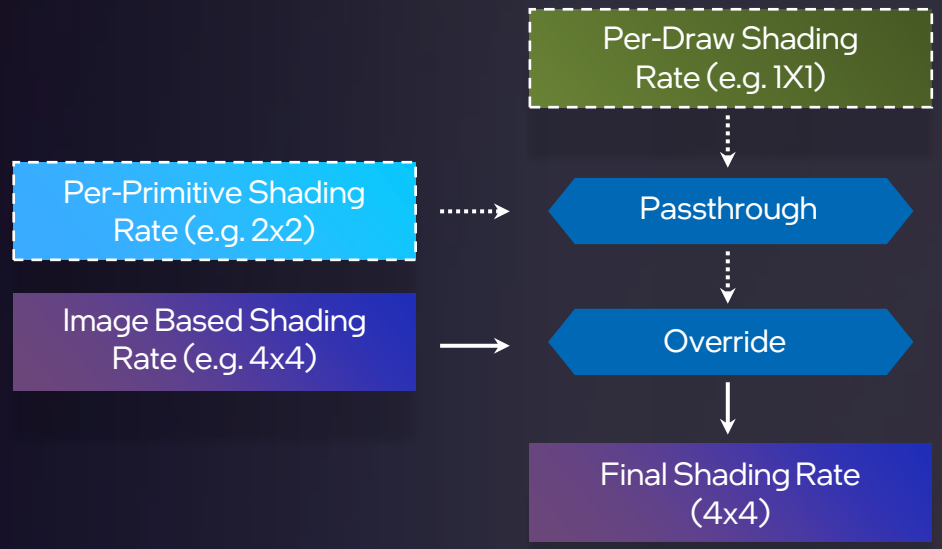
VRS Combiners in World of Warcraft

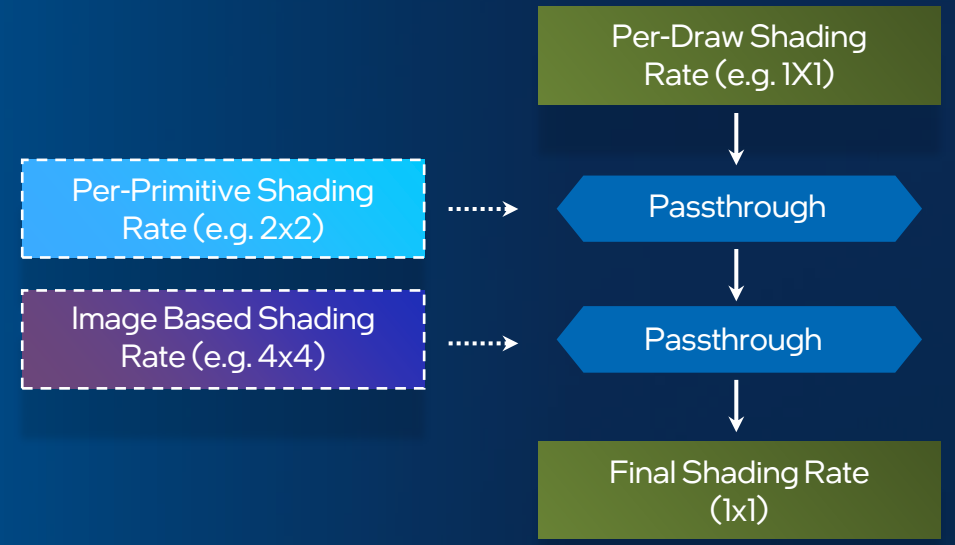
VALAR Image Based Override Combiner




```
D3D12_SHADING_RATE_COMBINER shadingRateCombinerVALAR[2] = {
  D3D12_SHADING_RATE_COMBINER_PASSTHROUGH,
  D3D12_SHADING_RATE_COMBINER_OVERRIDE
};

commandList->RSSetShadingRate(
  D3D12_SHADING_RATE_1X1, shadingRateCombinerVALAR);
```

Manual-Alpha Test Passthrough Combiner




```
D3D12_SHADING_RATE_COMBINER shadingRateCombinerHero[2] = {
  D3D12_SHADING_RATE_COMBINER_PASSTHROUGH,
  D3D12_SHADING_RATE_COMBINER_PASSTHROUGH
};

commandList->RSSetShadingRate(
  D3D12_SHADING_RATE_1X1, shadingRateCombinerHero);
```

VALAR DISABLED
3840x2160 Quality 5

*Images Courtesy of Blizzard Entertainment, Inc.

VALAR STANDARD
3840x2160 Quality 5

Sensitivity
Threshold: **0.31**

Quarter Rate Shading
Modifier: **2.13**

Environment
Luma: **0.05**

Weber-Fechner Mode:
Disabled

*Images Courtesy of Blizzard Entertainment, Inc.

VALAR AGGRESSIVE
3840x2160 Quality 5

Sensitivity
Threshold: **0.50**

Quarter Rate Shading
Modifier: **2.13**

Environment
Luma: **0.05**

Weber-Fechner Mode:
Disabled

*Images Courtesy of Blizzard Entertainment, Inc.

Side-By-Side Image Comparison

VALAR DISABLED

Resolution: 3840x2160
Quality Level: 5
Zoom: 100%

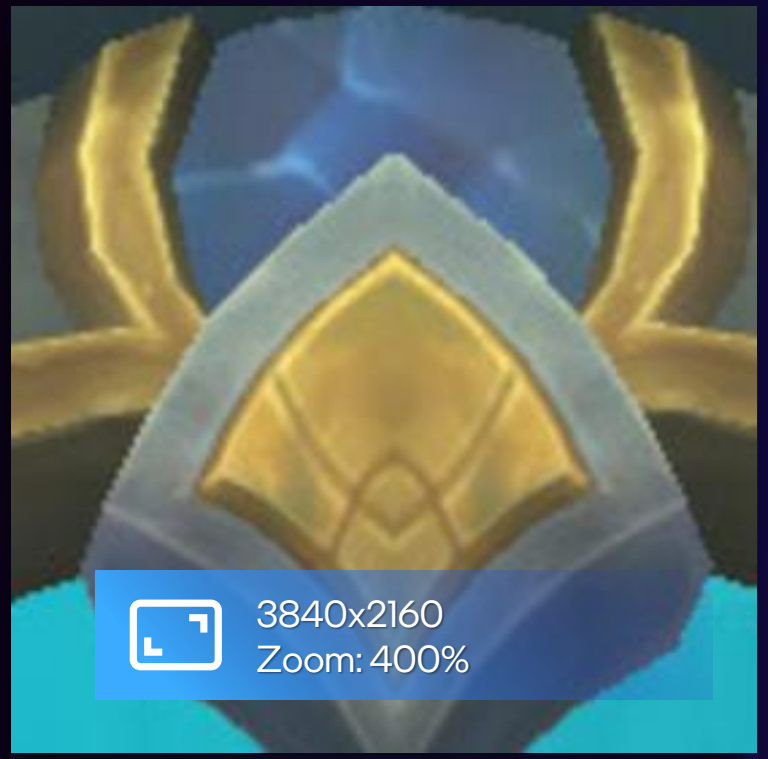
VALAR STANDARD

Sensitivity Threshold: **0.31**
Quarter Rate Shading Modifier: **2.13**
Environment Luma: **0.05**
Weber-Fechner Mode: **Disabled**

VALAR AGGRESSIVE

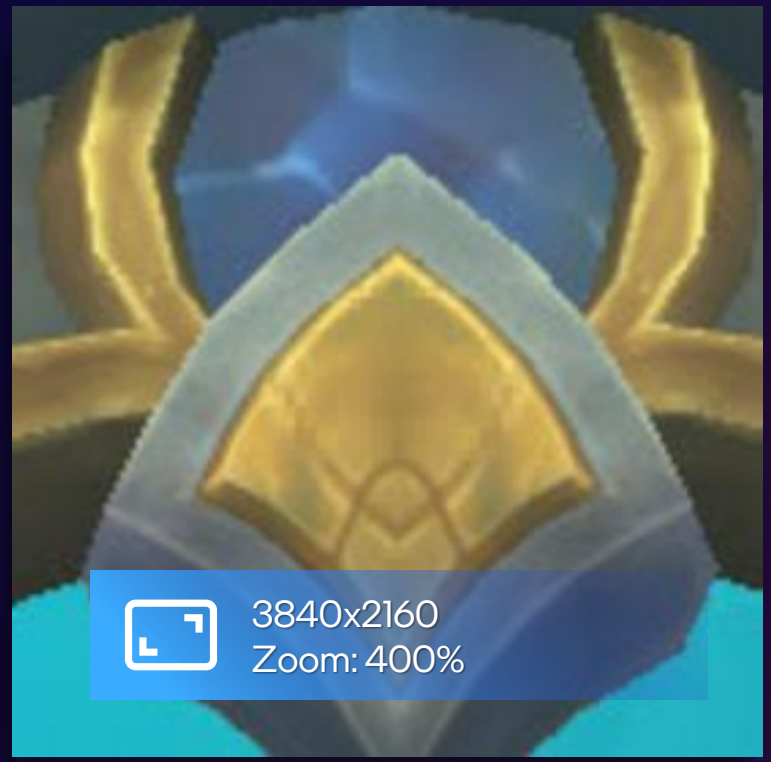
Sensitivity Threshold: **0.50**
Quarter Rate Shading Modifier: **2.13**
Environment Luma: **0.05**
Weber-Fechner Mode: **Disabled**

Side-By-Side Image Comparison



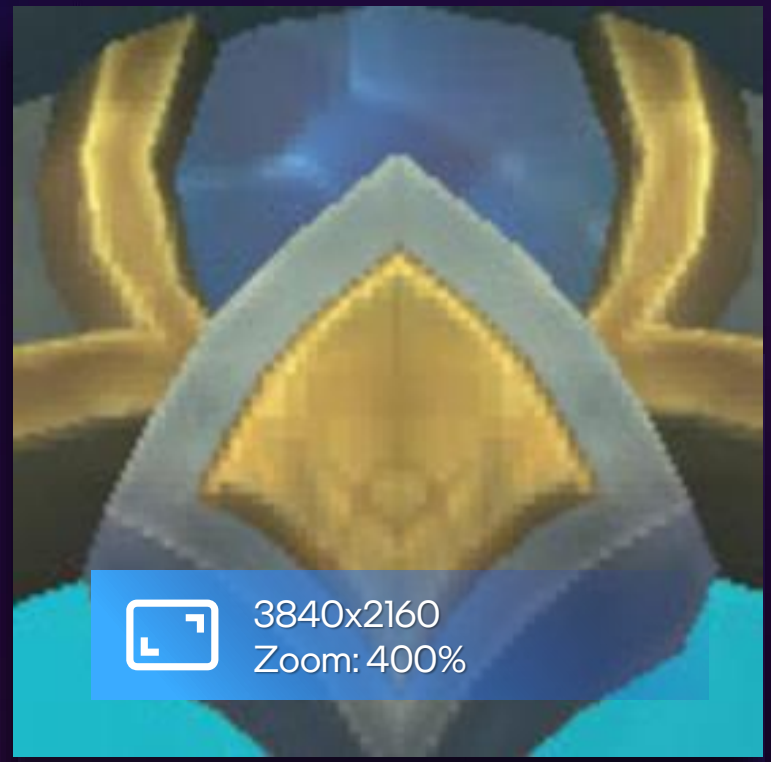
VALAR DISABLED

Resolution: 3840x2160
Quality Level: 5
Zoom: 400%



VALAR STANDARD

Sensitivity Threshold: **0.31**
Quarter Rate Shading Modifier: **2.13**
Environment Luma: **0.05**
Weber-Fechner Mode: **Disabled**



VALAR AGGRESSIVE

Sensitivity Threshold: **0.50**
Quarter Rate Shading Modifier: **2.13**
Environment Luma: **0.05**
Weber-Fechner Mode: **Disabled**

*Images Courtesy of Blizzard Entertainment, Inc.

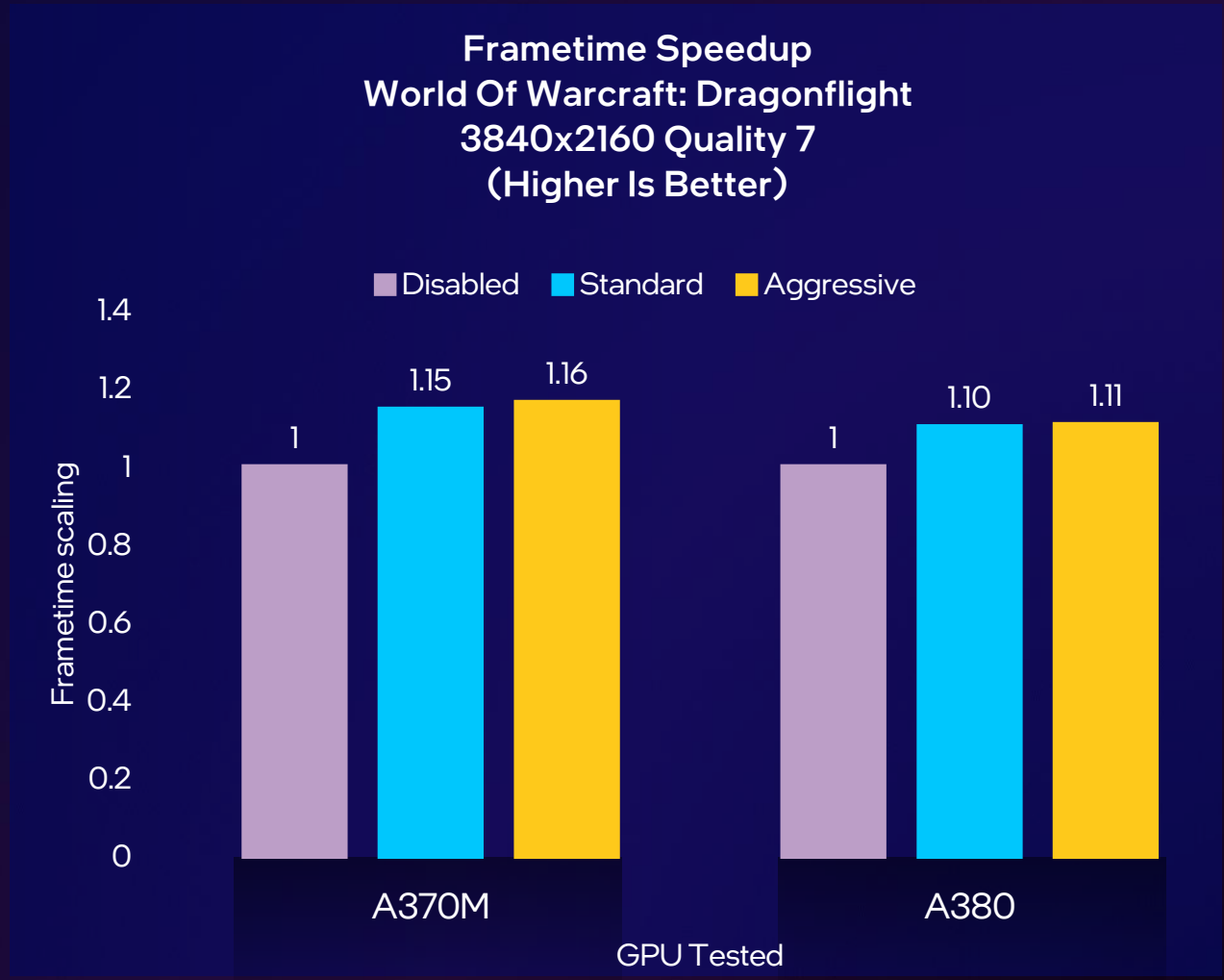
Performance Speedups

Test Configuration

- Standard Sensitivity: 0.31
- Aggressive Sensitivity: 0.50
- Quarter Rate Shading Modifier: 2.13
- Environment Luminance: 0.05
- Resolution: 3840x2160
- Quality Level: 7
- Area: Vol'Dun

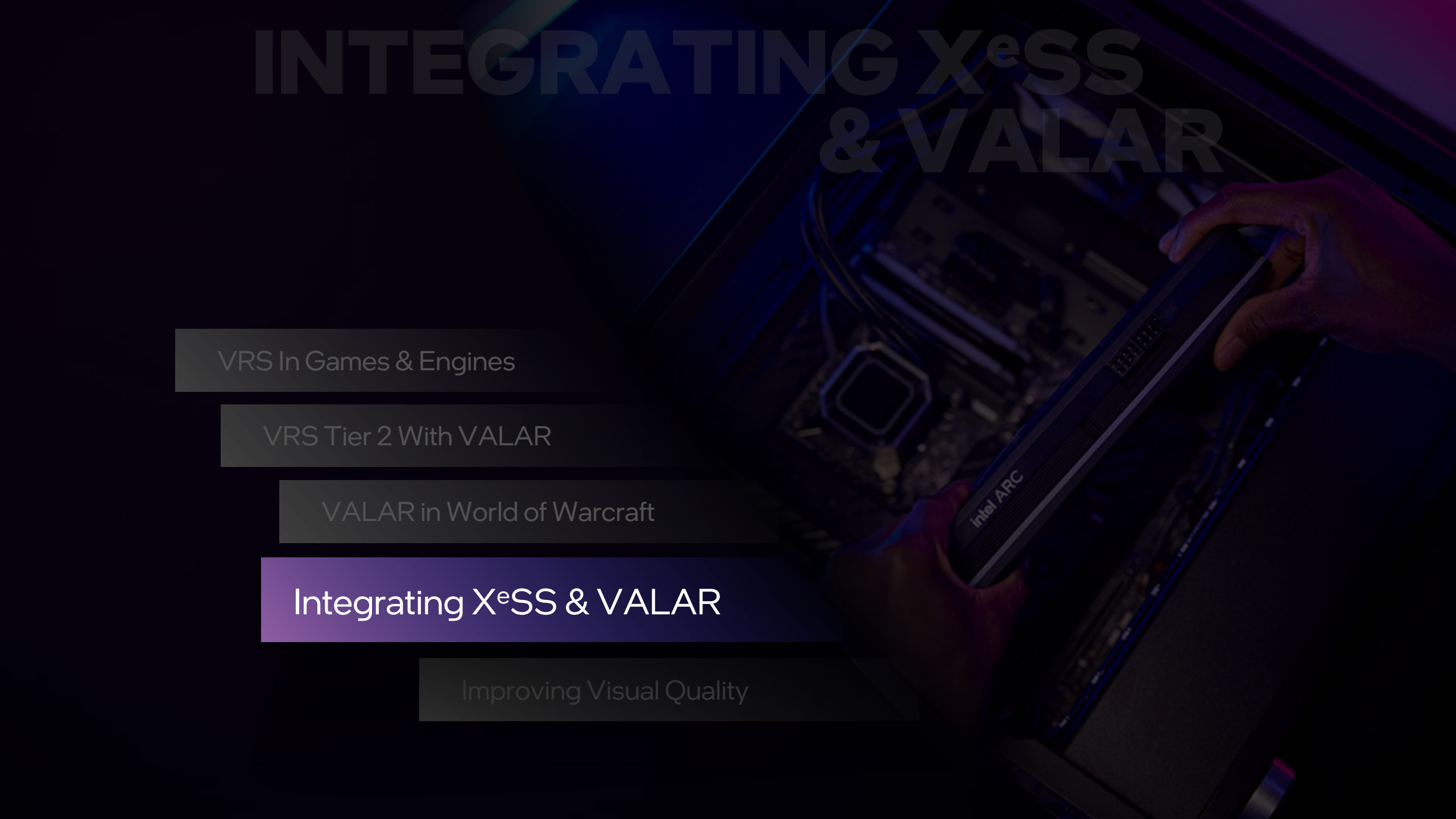
Frametime Scaling

- Intel® Arc A370M: Up to 1.15x to 1.16x
- Intel® Arc A380: Up to 1.10x to 1.11x



*Pre-production software, numbers subject to change.
Arc A370M: 12th Gen Intel(R) Core(TM) i7-12700H - Windows 11 Pro 64-bit (10.0, Build 22621) - 32768MB RAM
Arc A380: 12th Gen Intel(R) Core(TM) i5-12600K - Windows 11 Pro 64-bit (10.0, Build 22621) - 32768MB RAM

INTEGRATING XeSS & VALAR



VRS In Games & Engines

VRS Tier 2 With VALAR

VALAR in World of Warcraft

Integrating XeSS & VALAR

Improving Visual Quality

Integrating XeSS & VALAR

Xe Super-Sampling (XeSS)

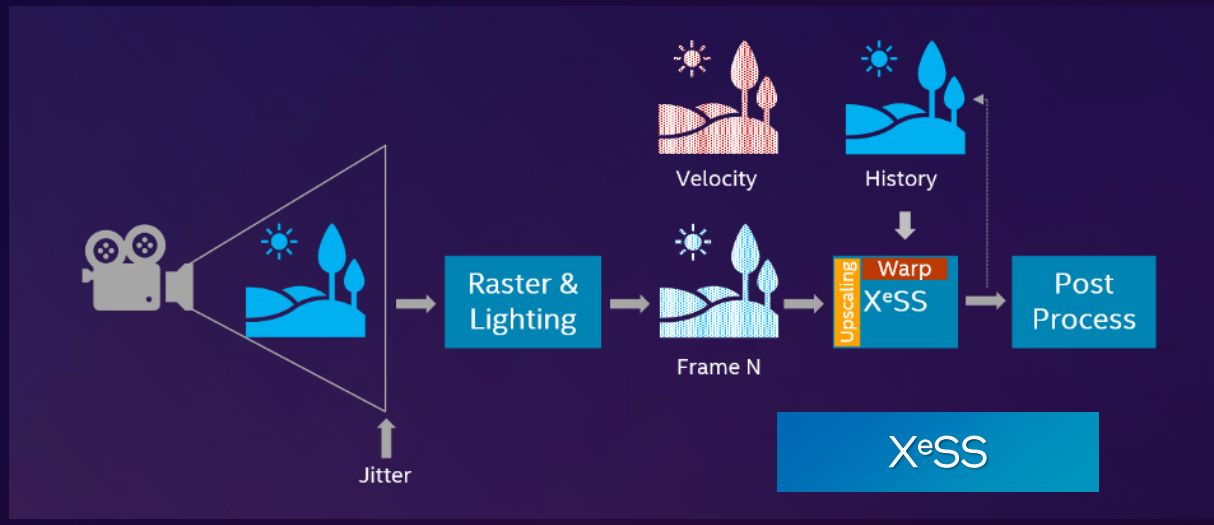
- Machine-Learning Based Super-Sampling
- Temporally Stable Anti-Aliased Output
- Low-Res & High-Res Motion Vectors
- Scaling Factors: Ultra, Quality, Balanced, Performance

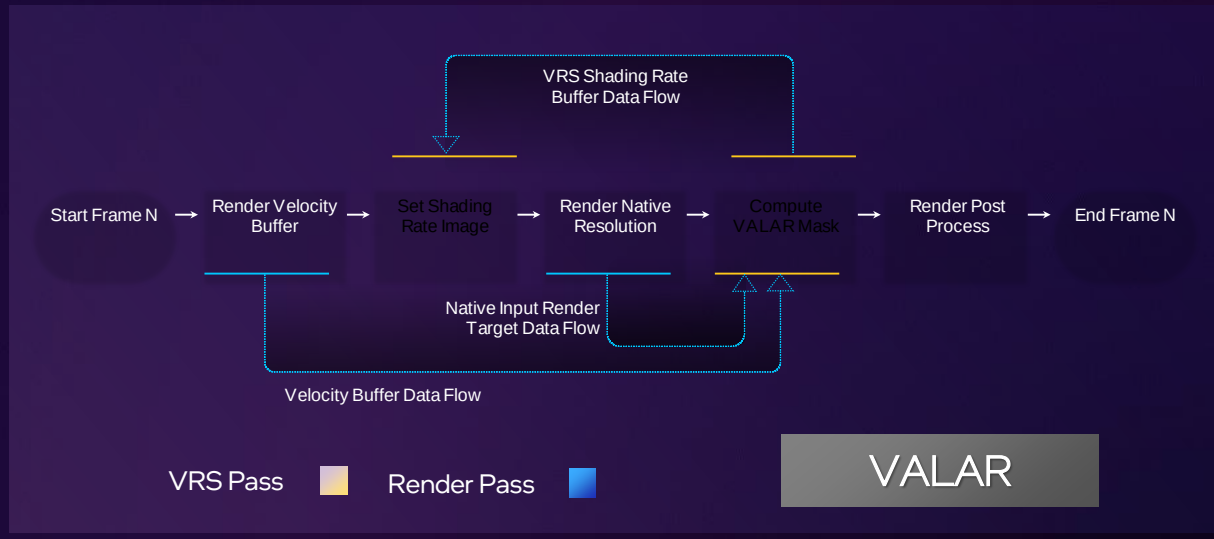
Velocity & Luminance Adaptive Rasterization

- VRS Tier 2 Based Sub-Sampling Technique
- Approximates "Perceptually Lossless" Output
- Low-Res & High-Res Motion Vectors
- Shader Performance Relative To Input Resolution

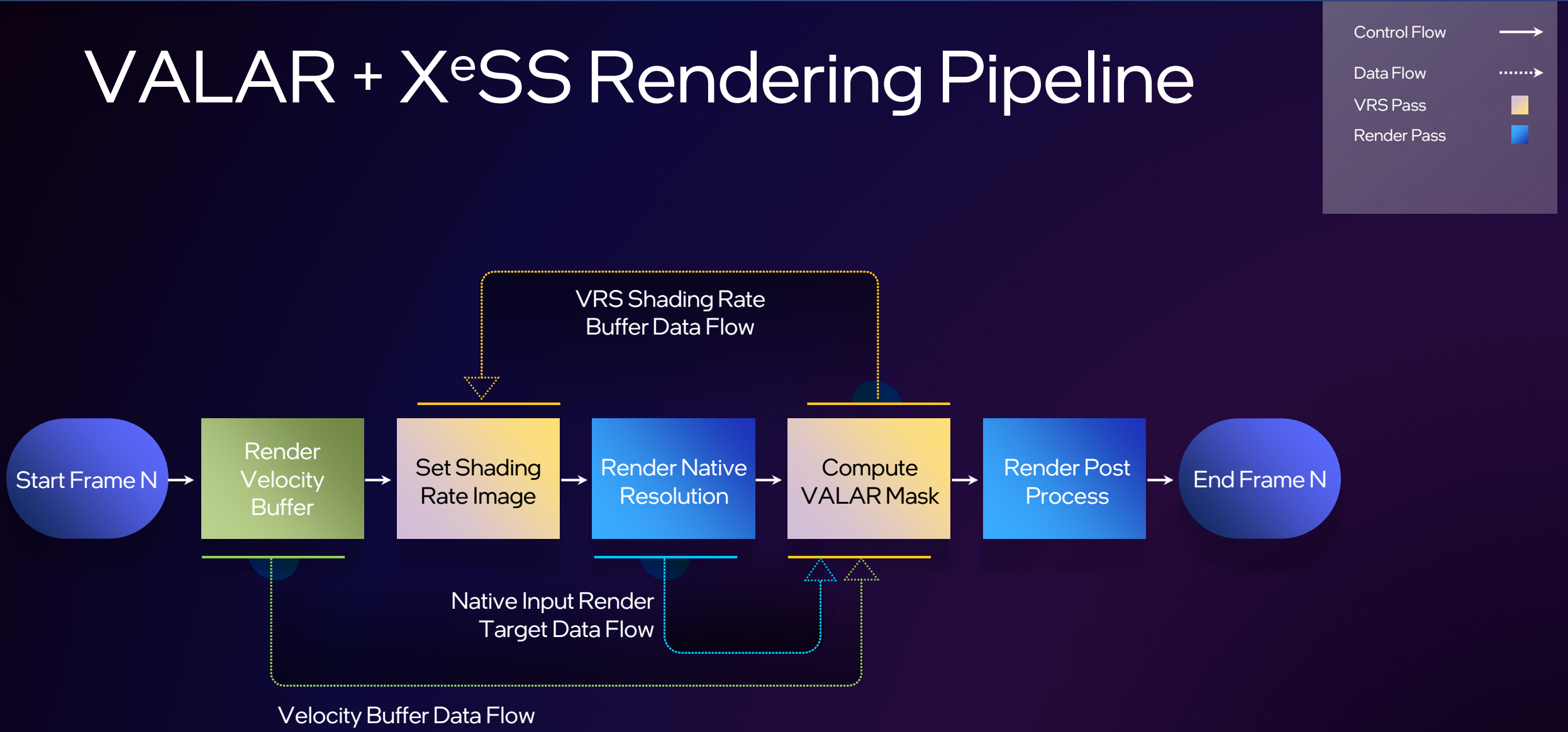
Considerations

- Mapping VRS Tiles to Upscaled Pixels
- Translating Between Coordinate Systems
- Low-Res & High-Res Motion Vectors
- Improving Visual Quality

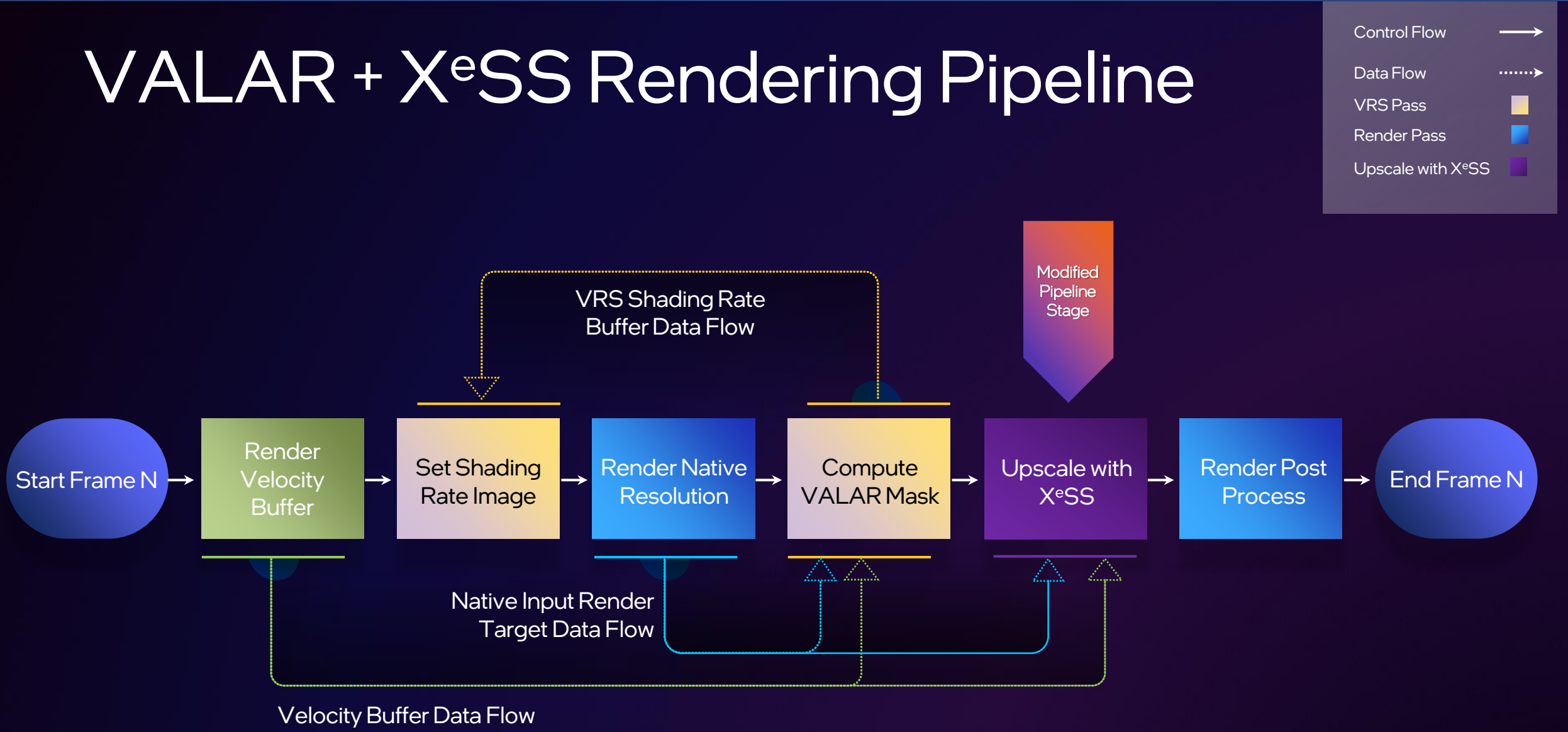




VALAR + XeSS Rendering Pipeline



VALAR + XeSS Rendering Pipeline



VRS Tile Sizes & Scaled Resolutions

Tile Sizes Defined by GPU Hardware

- $T = \begin{cases} 8, & \text{Intel;} \\ 16, & \text{Other.} \end{cases}$

Check Hardware Features

Number of Tiles Relative To Input Resolution

- $N_i = \left(\frac{w_i}{T}\right)\left(\frac{h_i}{T}\right)$
- $N_{2k} = \left(\frac{2560}{8}\right)\left(\frac{1440}{8}\right) = (320 \cdot 180) = \mathbf{57,600}$
- $N_{4k} = \left(\frac{3840}{8}\right)\left(\frac{1600}{8}\right) = (480 \cdot 200) = \mathbf{96,000}$

Common Scaling Factors for XeSS

- $S = \begin{cases} \mathbf{1.3}, & Ultra; \\ \mathbf{1.5}, & Quality; \\ \mathbf{1.7}, & Balanced; \\ \mathbf{2.0}, & Performance. \end{cases}$

Input And Upscaled Tile Sizes Are Not Equal

- $T_i = T^2$
- $T_u = (S \cdot T)^2$
- $T_u \geq T_i$

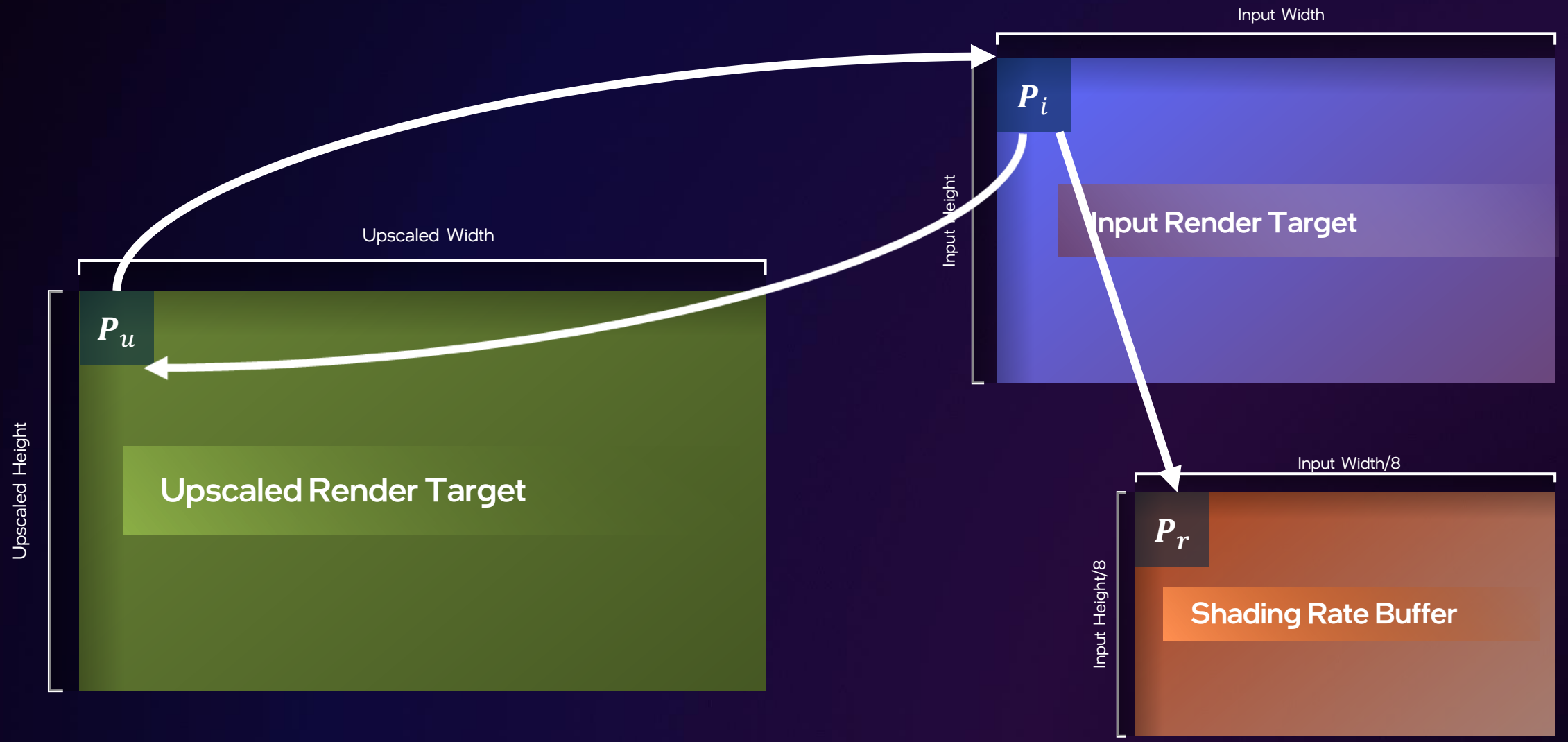
Number of Input Resolution Pixels Per Tile

- $P_{intel} = 8^2 = \mathbf{64}$
- $P_{other} = 16^2 = \mathbf{256}$

Number of Upscaled Pixels Per Tile

- $P_{ultra} = (1.3 \cdot 8)^2 \approx \mathbf{108}$
- $P_{quality} = (1.5 \cdot 8)^2 = \mathbf{144}$
- $P_{balanced} = (1.7 \cdot 8)^2 \approx \mathbf{185}$
- $P_{performance} = (2 \cdot 8)^2 = \mathbf{256}$

Pixel Coordinate Conversions



Scaling Pixel Coordinates

Compute The Scaling Ratio

$$S = \frac{I}{U}$$

2D Vectors

Convert From Upscaled To Input Resolution

$$P_i = S \cdot P_u$$

Convert From Input Resolution to VRS Tile

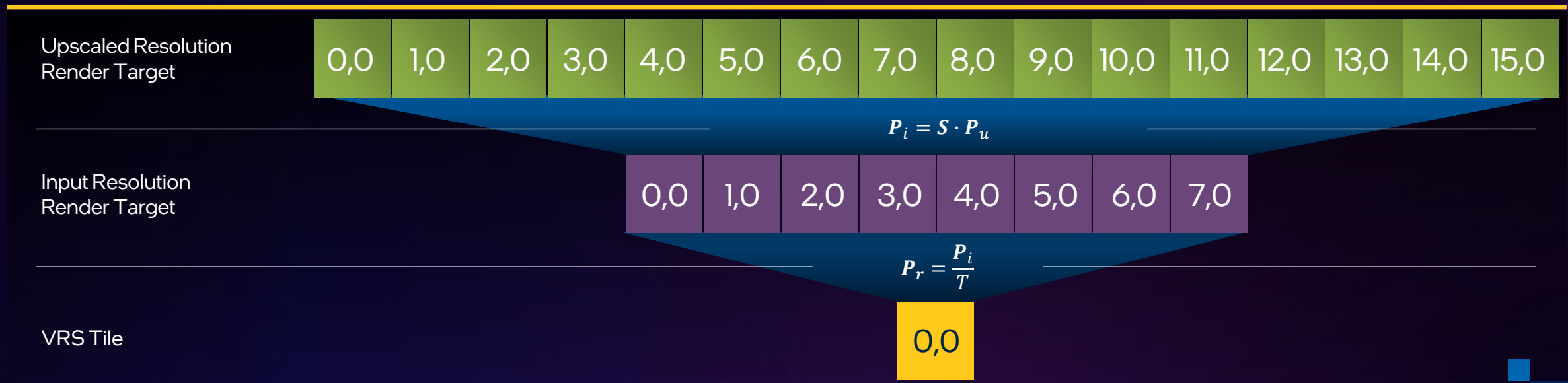
$$P_r = \frac{P_i}{T}$$

HW Tile Size

Convert From Input To Upscaled Resolution

$$P_u = \frac{P_i}{S}$$

$P_u \in P_u \ldots P_u + (T - 1)$



Low-Res & High-Res Motion Vectors

Low-Res Motion Vectors

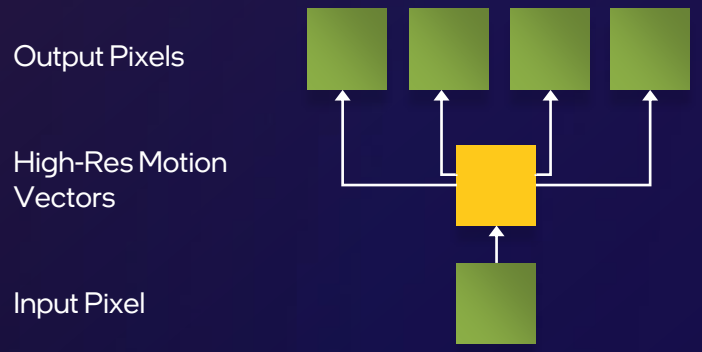
- Input And Motion Vector Resolution Are Equal
- Works out-of-the-box With VALAR
- Jittered Motion Vectors Can Improve Stability

High-Res Motion Vectors

- Output And Motion Vector Resolution Are Equal
- High-Res Motion Vector Support Added To VALAR
- Jittered Motion Vectors Can Improve Stability

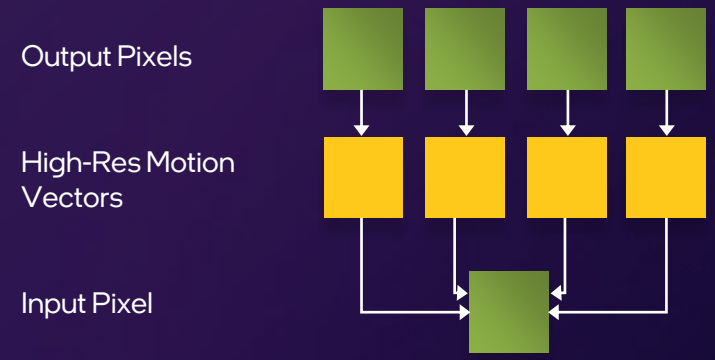
Low-Res Coordinate Conversion

- One Motion Vector to Many Output Pixels
- One-To-One With Input Pixels
- $P_i = S \cdot P_u$



High-Res Coordinate Conversion

- Many Motion Vectors to One Input Pixel
- Sampling Pattern or Min/Max/Median/Average
- $P_u = \frac{P_i}{S}$ where $P_u \in P_u \ldots P_u + (T - 1)$



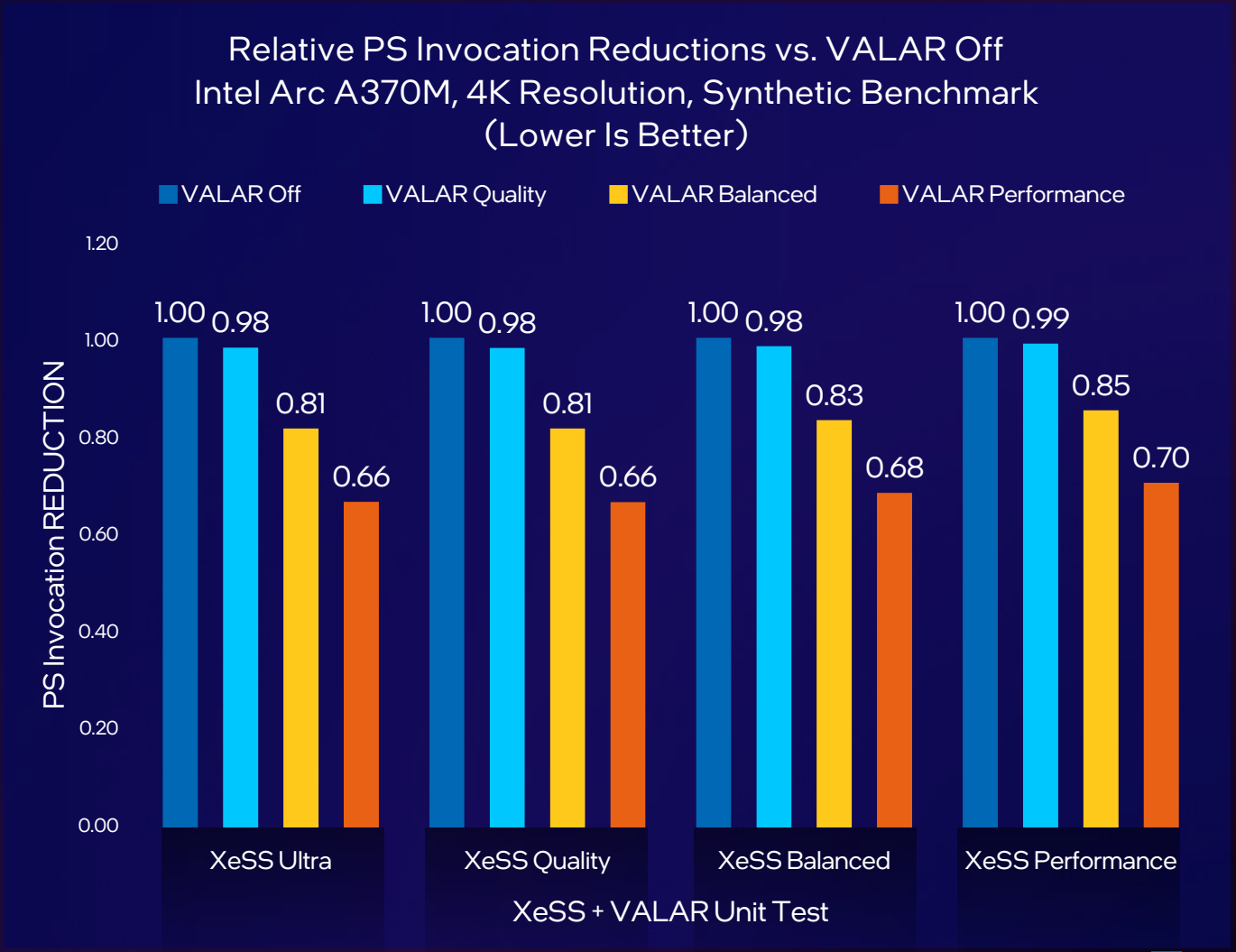
XeSS + VALAR Pixel Shader Invocations

Experimental Setup

- XeSS Mode + VALAR Mode
- Relative Reduction in PS Invocations
- Versus Control: XeSS Mode + VALAR OFF
- VALAR Quality: Sensitivity = 0.25
- VALAR Balanced: Sensitivity = 0.50
- VALAR Performance: Sensitivity = 0.75

Observations

- PS Invocations Relative to VALAR Sensitivity
- VALAR Quality: ~1-2% Reduction
- VALAR Balanced: ~15-20% Reduction
- VALAR Performance: ~30-34% Reduction



***Pre-production software, numbers subject to change.**
12th Gen Intel(R) Core(TM) i7-12700H - Windows 11 Pro 64-bit (10.0, Build 22621) - 32768MB RAM

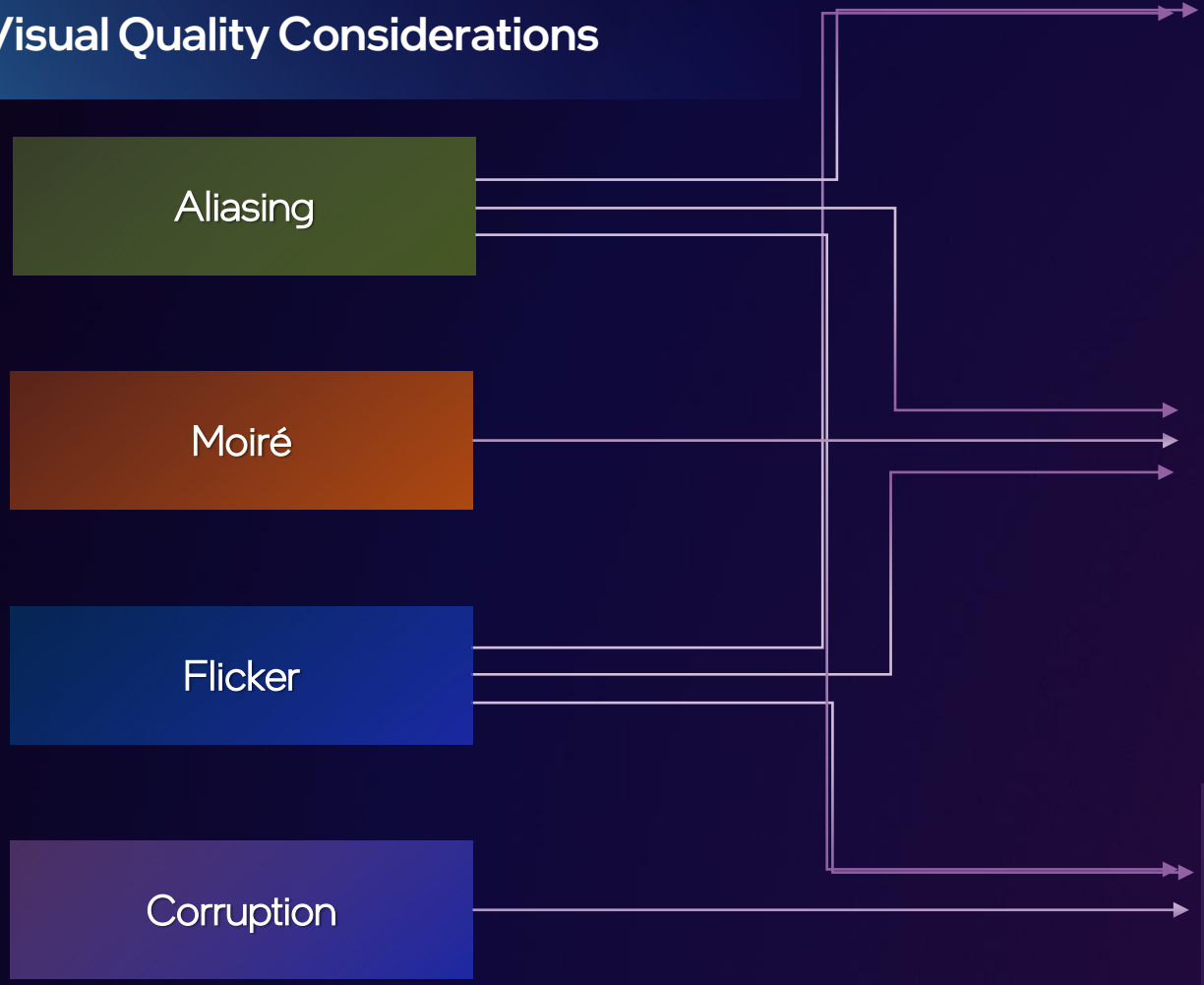
IMPROVING VISUAL QUALITY

- VRS In Games & Engines
- VRS Tier 2 With VALAR
- VALAR in World of Warcraft
- Integrating XeSS & VALAR
- **Improving Visual Quality**

Visual Quality Improvement Strategies

Visual Quality Considerations

- Aliasing
- Moiré
- Flicker
- Corruption



VALAR Quality Tuning

- Parameter Tuning
- 2x2 Only Mode
- Weber-Fechner Mode
- Dynamic Threshold
- Relaxed Mode

XeSS Quality Tuning

- Quality Modes
- Mip-Biasing
- Sharpening
- Jittered Motion Vectors

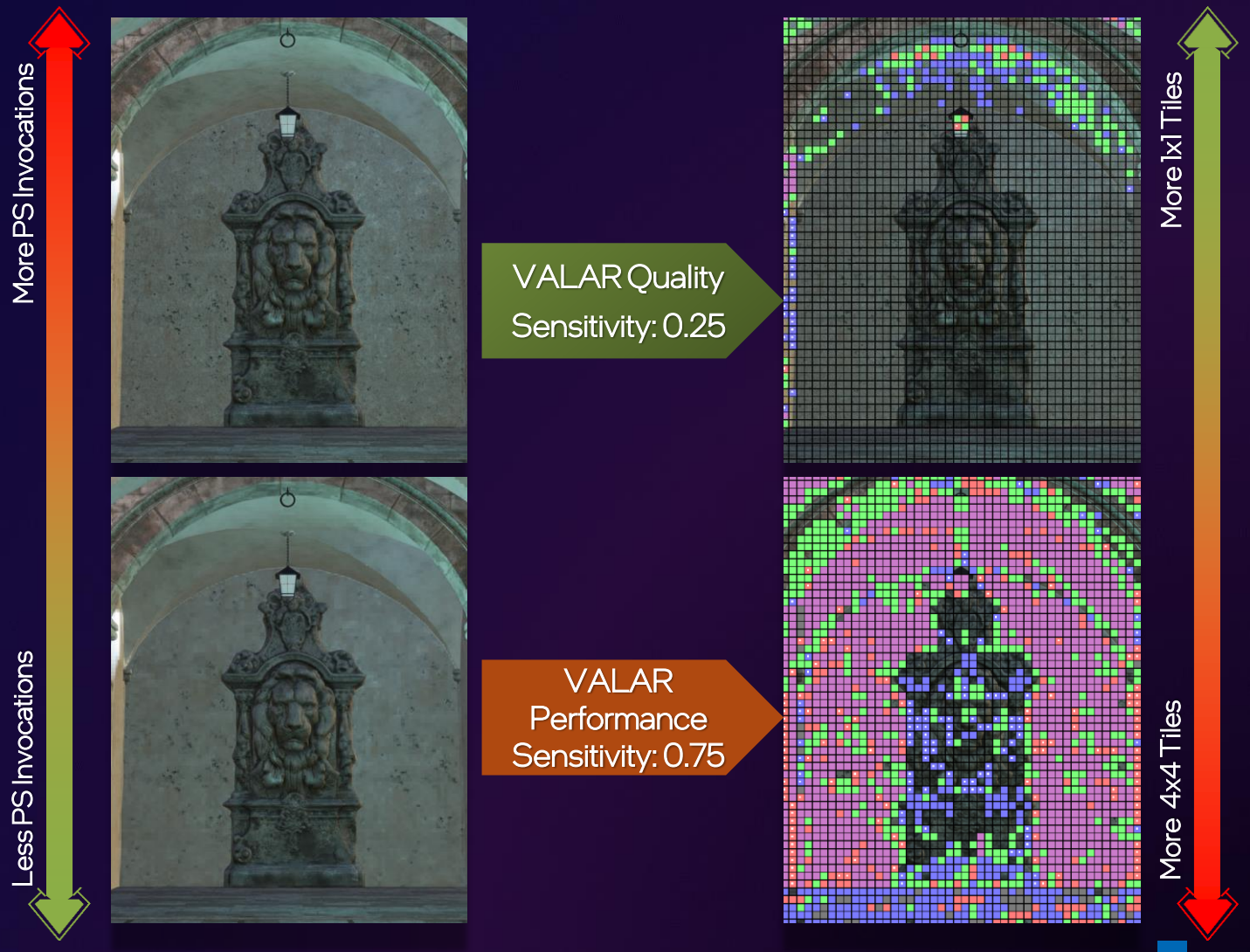
API Quality Tuning

- VRS Combiners
- Multiple Command Lists

VALAR Quality Tuning

Sensitivity Threshold (T)

- Primary Threshold For JND
- Consider Quality Modes
  - Quality: 0.25
  - Balanced: 0.50
  - Performance: 0.75



$$JND = \boldsymbol{T} \cdot (\bar{L}_t + E)$$

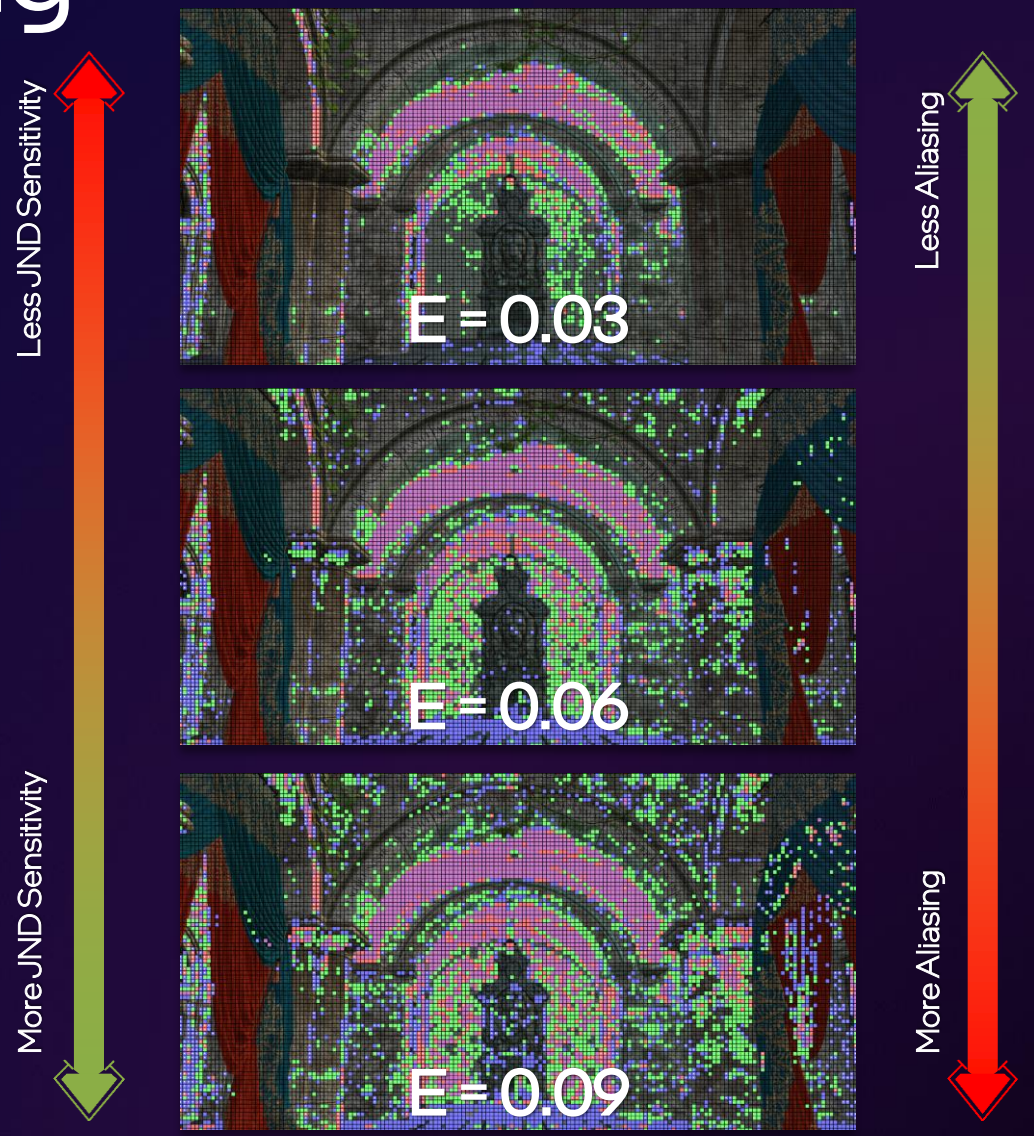
VALAR Quality Tuning

Sensitivity Threshold (T)

- Primary Threshold For JND
- Consider Quality Modes
  - Quality: 0.25
  - Balanced: 0.50
  - Performance: 0.75

Environment Luminance (E)

- Added To Average Luma in JND
- Use In Low Light Conditions
- Use GI Value [optional]



$$JND = \boldsymbol{T} \cdot (\bar{L}_t + E)$$

VALAR Quality Tuning

Sensitivity Threshold (T)

- Primary Threshold For JND
- Consider Quality Modes
  - Quality: 0.25
  - Balanced: 0.50
  - Performance: 0.75

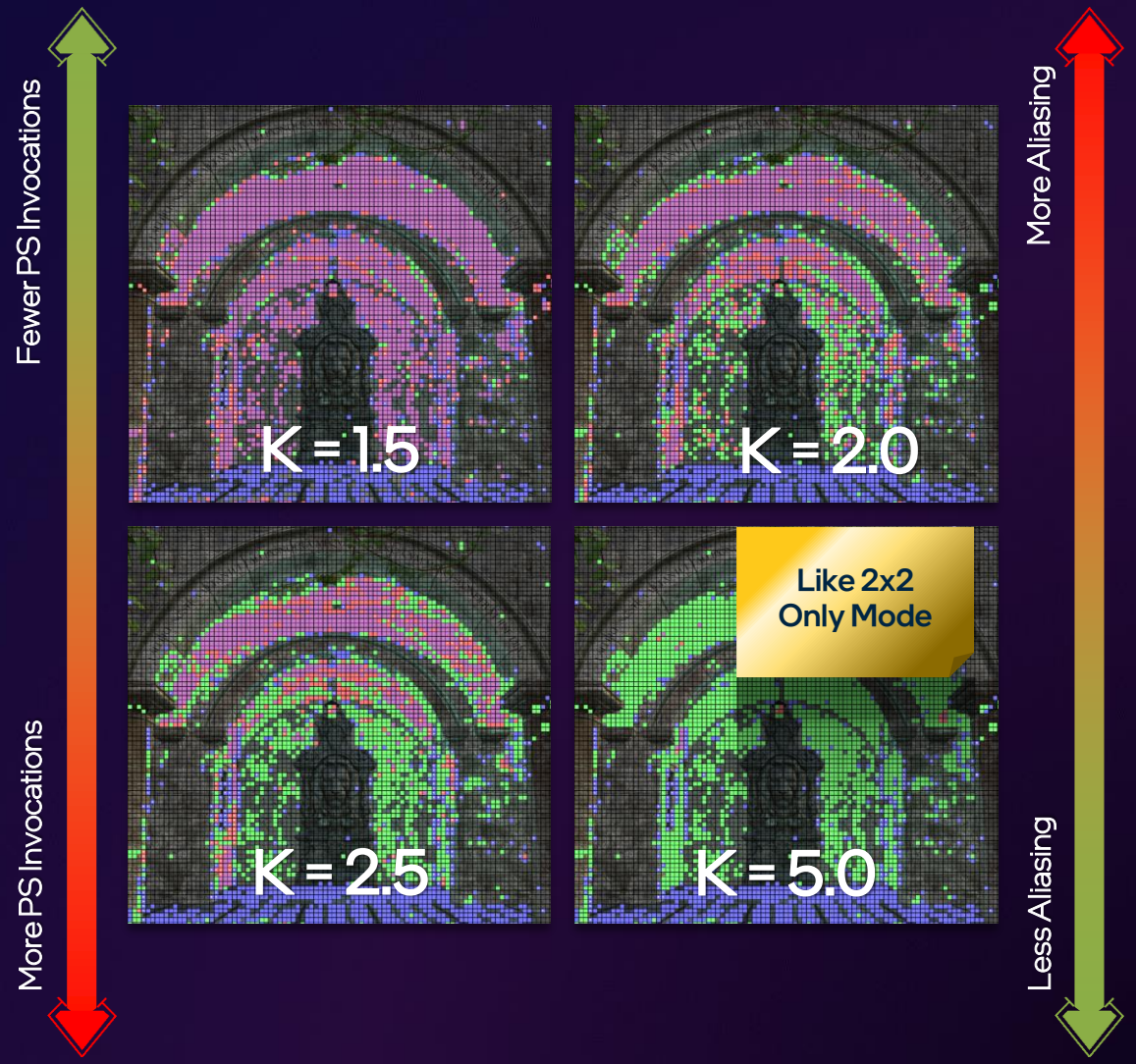
Environment Luminance (E)

- Added To Average Luma in JND
- Use In Low Light Conditions
- Use GI Value [optional]

Quarter Rate Shading Modifier (K)

- Controls 2x4, 4x2, and 4x4
- Part of Luma/Velocity MSE
- Recommended: 2.13 [Yang, 2019]
- High Values Decrease Quarter Rate

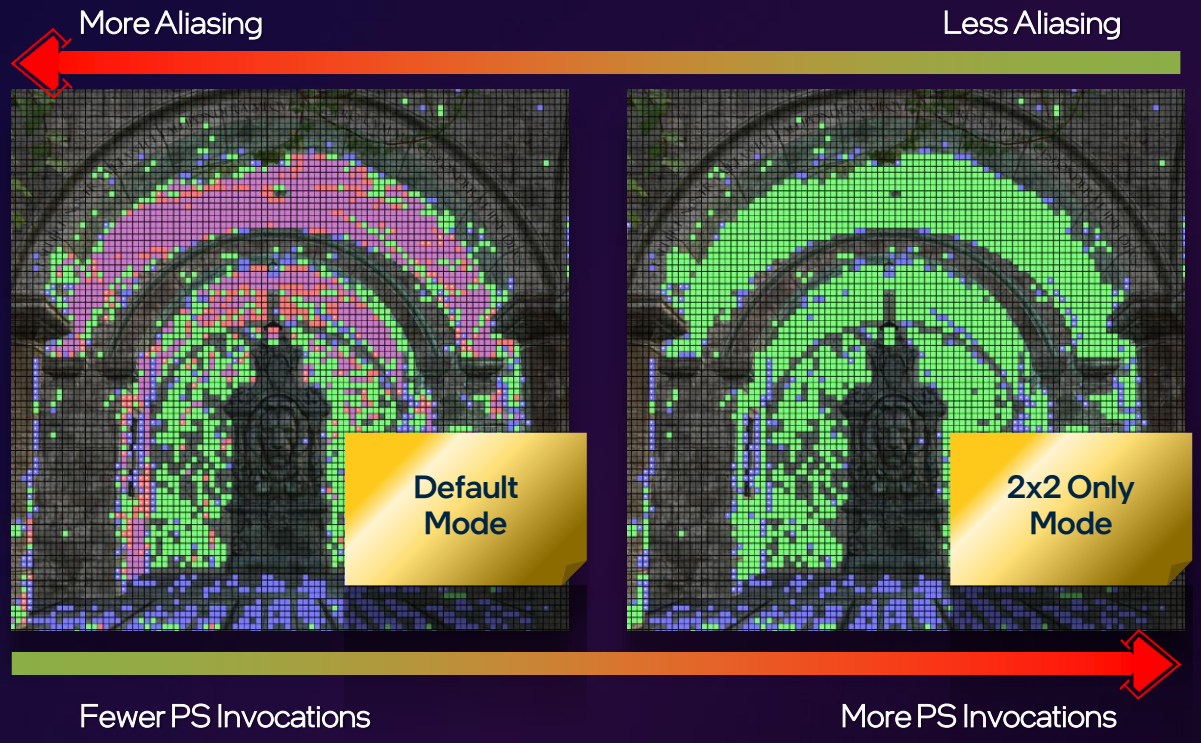
$$JND = \boldsymbol{T} \cdot (\bar{L}_t + E)$$



VALAR Optional Modes

2x2 Only Mode

- Disables 2x4, 4x2, and 4x4
- Increases 2x2 Tiles
- Reduces Aliasing In Coarse Pixels



VALAR Optional Modes

2x2 Only Mode

- Disables 2x4, 4x2, and 4x4
- Increases 2x2 Tiles
- Reduces Aliasing In Coarse Pixels

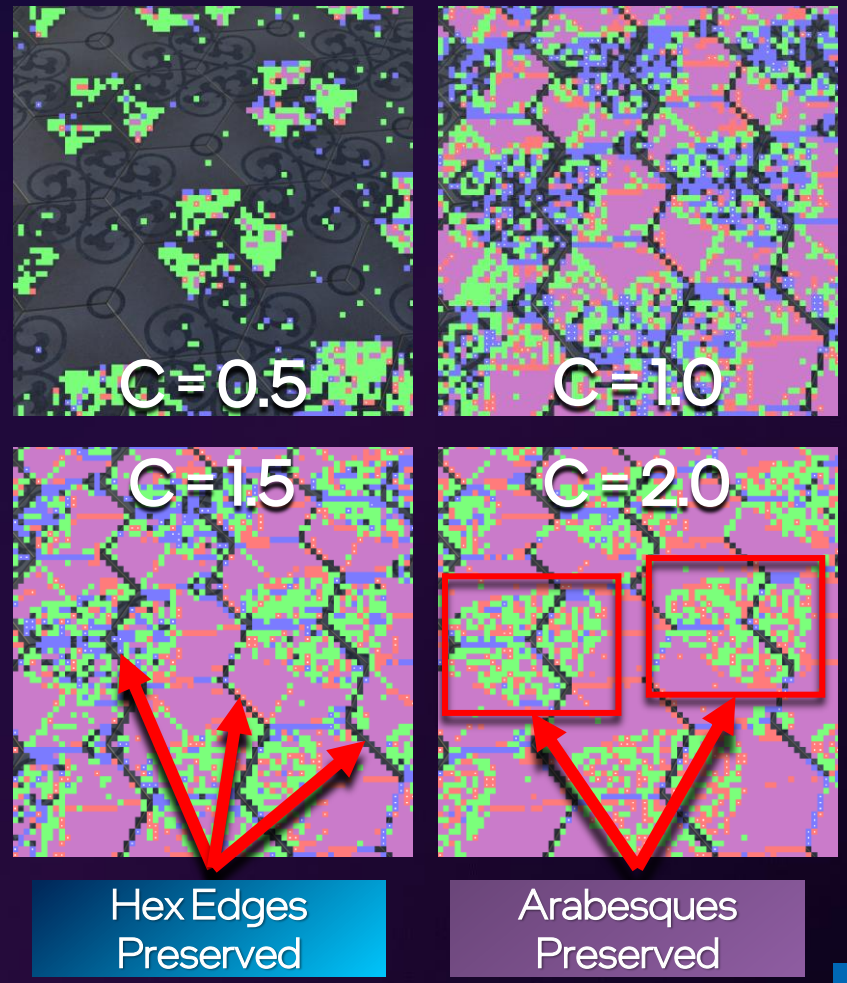
Weber-Fechner Mode

- Improves Precision of MSE
- Reads Neighborhood Luminance
- Weber-Fechner Constant (C)
- Tunable Precision with C

Bistro Scene

More Conservative

Default Setting



Hex Edges Preserved

Arabesques Preserved

VALAR Optional Modes

2x2 Only Mode

- Disables 2x4, 4x2, and 4x4
- Increases 2x2 Tiles
- Reduces Aliasing In Coarse Pixels

Weber-Fechner Mode

- Improves Precision of MSE
- Reads Neighborhood Luminance
- Weber-Fechner Constant (C)
- Tunable Precision with C

Dynamic Threshold

- Enable / Disable VRS Techniques
- Auto-Adjust VALAR Sensitivity
- When GPU Bound
- Exceeding Target Framerate

GPU Bound Toggle

$$VALAR = \begin{cases} ON, & \bar{t}_{gpu} \geq \bar{t}_{cpu} - (\sim 0.05 \cdot \bar{t}_{cpu}); \\ OFF, & otherwise. \end{cases}$$

Exceeding Target Framerate

$$T = \frac{\bar{t}_{gpu}}{1000 \cdot t_{fps}} \; where \; \boldsymbol{T} \; is \; the \; sensitivity \; threshold$$

Relaxed Mode & Relaxed Mode Plus

Relaxed Mode

- $VALAR = \begin{cases} DISABLED, & C_N - C_{N-1} = 0; \\ ENABLED, & otherwise. \end{cases}$

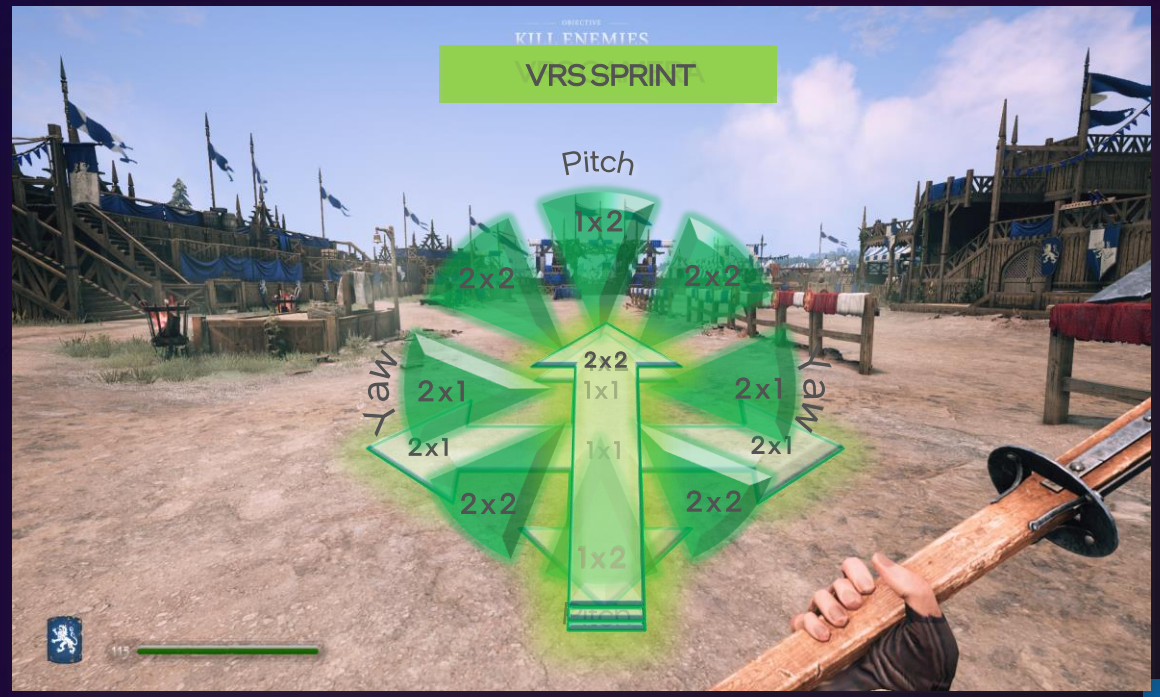
Relaxed Mode Plus

- $R_x = \begin{cases} R_2, & \leftarrow C \rightarrow; \\ R_1, & otherwise. \end{cases}$
- $R_y = \begin{cases} R_2, & \uparrow C \downarrow; \\ R_1, & otherwise. \end{cases}$
- $R_{xy} = \begin{cases} R_2, & \swarrow C \nearrow \; or \; \nwarrow C \searrow; \\ R_1, & otherwise. \end{cases}$

Chivalry II by Tripwire*

- Released in 2021
- VRS Tier 1 Relaxed Mode Plus
- Enabled VRS When Camera or Player Moves

Motion & Motion Blur Obscure Aliasing



*Images Courtesy of Tripwire Interactive

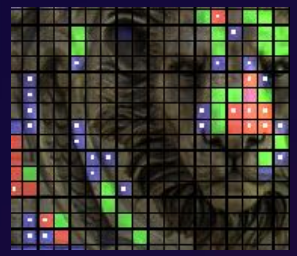
XeSS Quality Tuning

Quality Modes

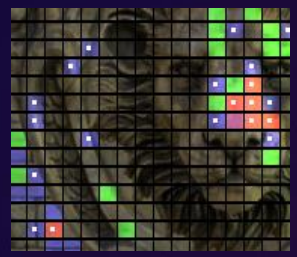
- Lower Scaling Factors May Reduce Aliasing
- Lower Scaling Factors May Reduce Flicker
- Lower Scaling Factors Decrease VRS Coverage
- Higher Scaling Factors Improve Performance

More VRS Coverage

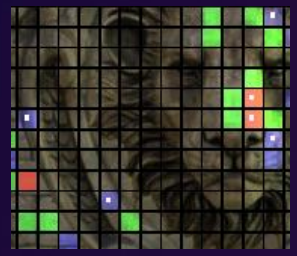
Less VRS Coverage



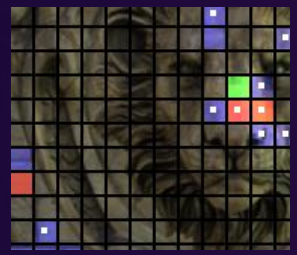
1080p - XeSS Ultra - VALAR Balanced
~18x15 Tiles → ~64 Shaded Tiles



1080p - XeSS Quality - VALAR Balanced
~16x14 Tiles → ~40 Shaded Tiles



1080p - XeSS Balanced - VALAR Balanced
~13x12 Tiles → ~20 Shaded Tiles



1080p - XeSS Perf - VALAR Balanced
~12x10 Tiles → ~13 Shaded Tiles

Higher VRS Precision

Lower VRS Precision

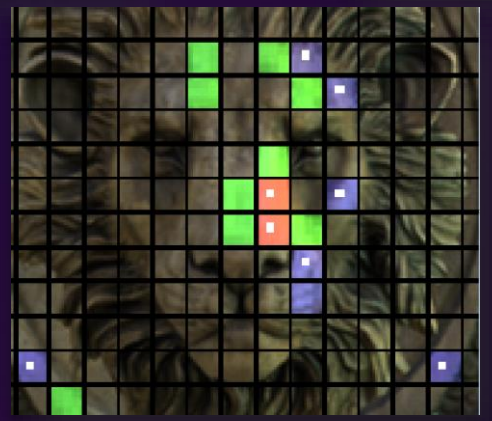
XeSS Quality Tuning

Quality Modes

- Lower Scaling Factors May Reduce Aliasing
- Lower Scaling Factors May Reduce Flicker
- Lower Scaling Factors Decrease VRS Coverage
- Higher Scaling Factors Improve Performance

Sharpening

- Blurs Or Sharpens Upscaled Output
- Helps Hide Aliasing From VALAR



XeSS Quality Tuning

Quality Modes

- Lower Scaling Factors May Reduce Aliasing
- Lower Scaling Factors May Reduce Flicker
- Lower Scaling Factors Decrease VRS Coverage
- Higher Scaling Factors Improve Performance

Sharpening

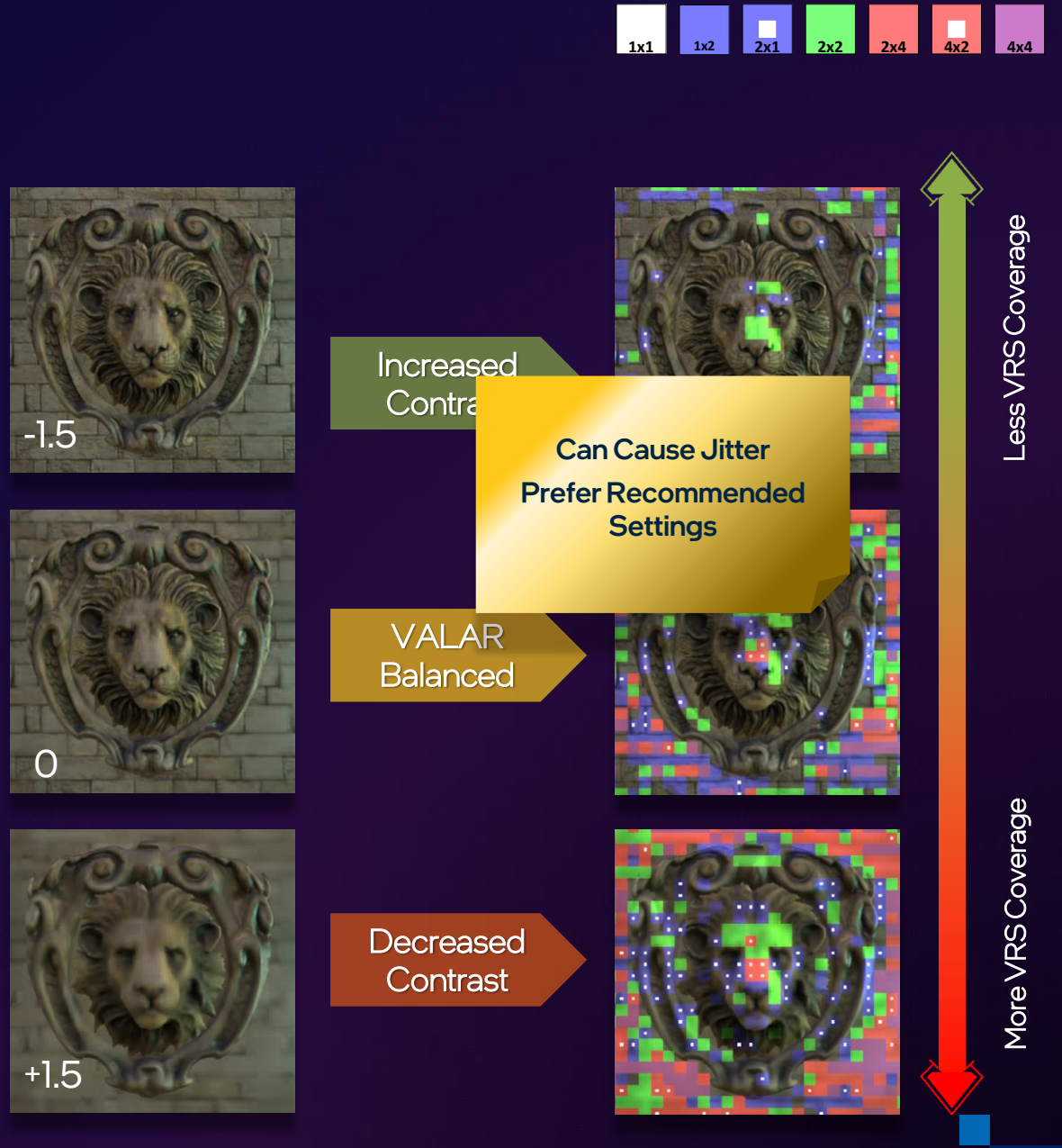
- Blurs Or Sharpens Upscaled Output
- Helps Hide Aliasing From VALAR

Mip-Biasing

- Selectively Biases Mip-Levels
- Helps Control Moiré From XeSS
- Contrast Affects VALAR Sensitivity

Jittered Motion Vectors

- Can Help Reduce Flickering

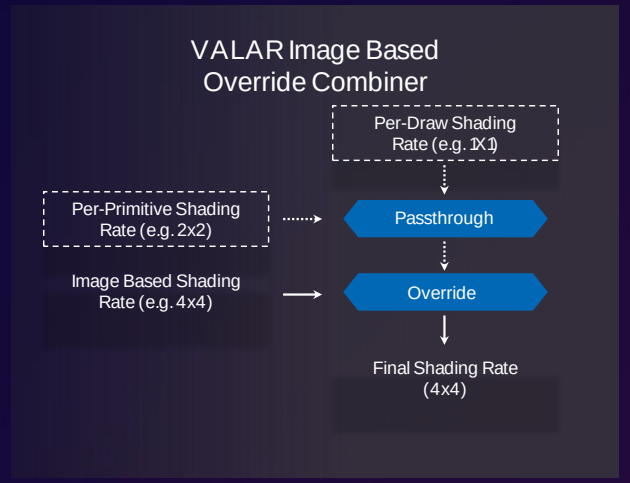


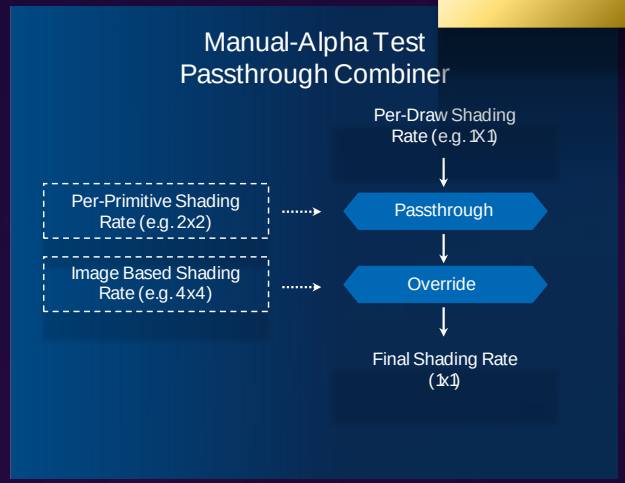
API Quality Tuning

Used in World of Warcraft

VRS Combiners

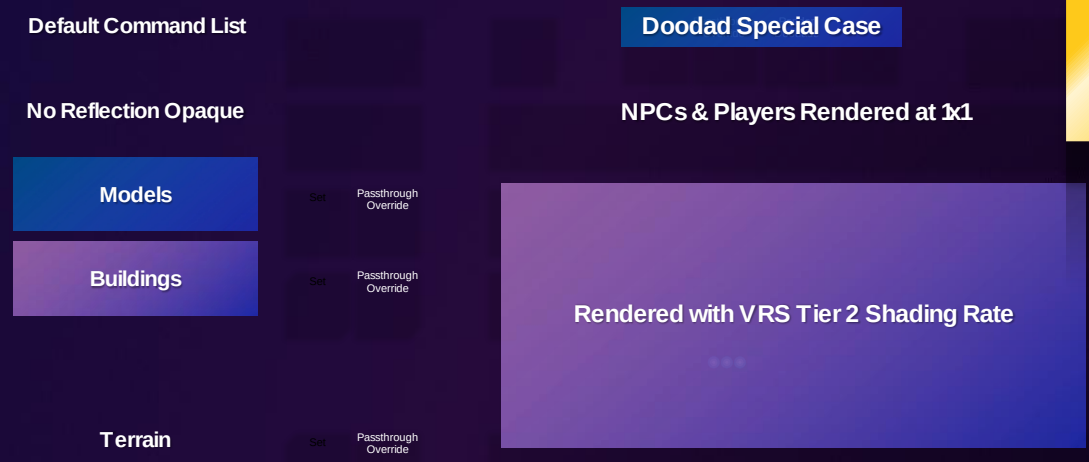
- Passthrough-Passthrough
  - ‘Hero’ Assets
  - Flickering (VRS)
  - Visual Corruption
- Passthrough-Override
  - Image Mask Overrides Tier 1





Multiple Command Lists

- High Quality Command List
  - ‘Hero’ Assets
  - Flickering (VRS)
  - Visual Corruption
- VRS Tier 2 Command List
  - Multiple VRS Image Masks



Used in World of Warcraft

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Paul DeBerry
Max Rahm
John Lytle
Blizzard Compat Lab

Microsoft
Claire Andrews
Shawn Hargreaves

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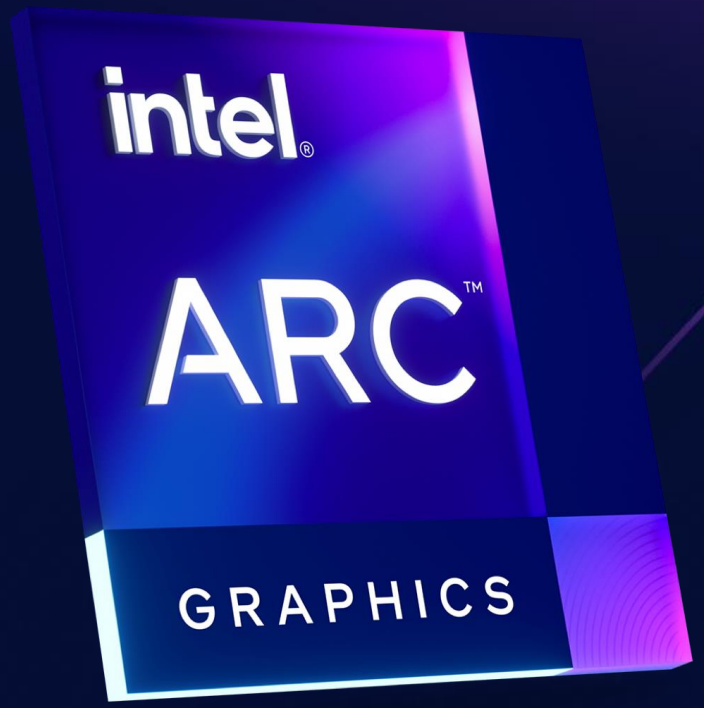

Thank you

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