Arrow Lake NPU Introduction and Features

Technical Training Material

WW03, January 2024

intel.

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Agenda

- Client AI and Roadmap
- What is NPU?
- What is MEP (Windows* Studio)?
- Arrow Lake (ARL) NPU POR Features
- ARL Audio Processing Object (APO)
- NPU Software Enabling and Experiences
- Q and A

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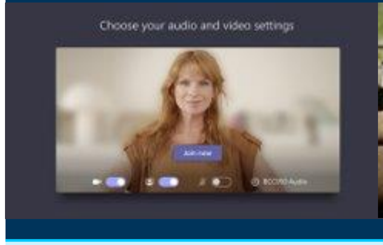
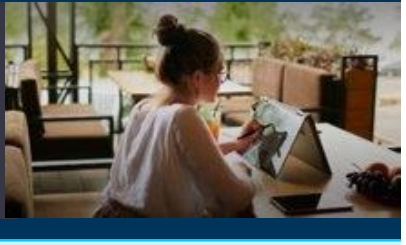
Client AI and Roadmap

Transforming the PC Experience





AI Today

Enhancements

Elevated video collaboration & streaming
Enhanced Audio effects
Creator and Gaming effects

Cloud

Massive scalable compute
High Latency
Privacy Concerns
Expensive

AI Tomorrow

Everything

AI Assistants know your daily context
More creative, productive, & collaborative
Across everything you do

Client

Massive distributed scale
Low Latency
Improved Privacy
Lower Cost (to ISV)

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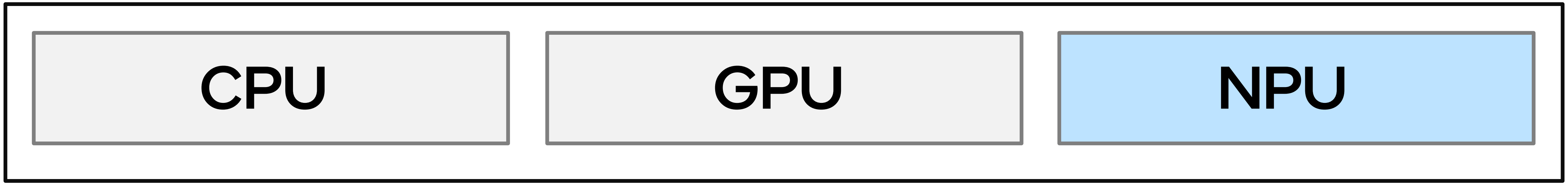
AI Inflection Point

Microsoft* believes that neural processing units, like Intel's NPU, represent an inflection point in computing and will be key to delivering a whole new range of delightful experiences to Windows* users on their PCs. These experiences will transform how people use their computers and connect with others.



Launching New Client Compute Capacity at Scale

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8Q Client AI Roadmap

CPU

Fast Response, Low latency

iGPU

AI integrated with 3D/render/ media pipelines; high batch size

NPU

Sustained Workloads, dedicated offload

	Meteor Lake		Lunar Lake (MX 17W)	Arrow Lake		Panther Lake	
CPU	6 (45W)		5	9 (45W)	14	5	11 (45W)
	U-series	H-series		H-series	S-series	U-series	H-series
iGPU	8	19	59	72	9	41	123 (45W)
NPU	11		45	11	13	48	48
Platform TOPS	25	36	109	Up to 92	Up to 36	98	182

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8Q Client AI Roadmap (Cont.)

Client AI Workloads are Diverse
No Single Compute Unit Meets All Key Needs

Bursty, Latency sensitive

Sustained, Battery life sensitive

Periodic, Throughput sensitive

HW	Value	RPL	MTL	ARL	LNL MX	PTL
CPU	SW Programmability; low latency, single inference tasks	**AVX-256 VNNI** H: 4-5 TOPS	**AVX-256 VNNI** H: ~3-6; U: ~2-3 TOPS	**AVX-256 VNNI** H: ~7-9.5; S: 14 TOPS	**AVX-256 VNNI** ~2-5 TOPS	**AVX2+** TOPS - H: Up to 11; U: 5
iGPU	AI integrated with 3D/render/ media pipelines; high batch size	**DP4A** H/U: up to 9 TOPS S/HX: 3 TOPS	**DP4a** (U, H) H: up to 19 TOPS U: up to 8 TOPS	**DP4a (U, S, HX)** ~9 TOPS **ARL H w/X^e Matrix Extensions (XMX)** Up to 72 TOPS	**DP4a + X^e Matix Extensions (XMX)** Up to 59 TOPS	**DP4a + XMX** H: Up to ~123 TOPS U: up to 41 TOPS
iNPU	Dedicated AI Offload, Power efficiency for Battery Life	**NA**	**NPU 2.7** TOPS - H: 11 TOPS; U: 9.5-11; ARL S, HX: 13		**NPU 4.0** Up to 45 TOPS	**NPU 5.0** Up to 48 TOPS

TOPS will vary slightly based on power & frequency of each sku

The Right Frameworks for Innovation and Scale:

DirectML

OpenVINO™

ONNX

W3C®
WebAssembly
WebGPU
WebNN

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What is NPU?

Arrow Lake: Neural Processor Unit

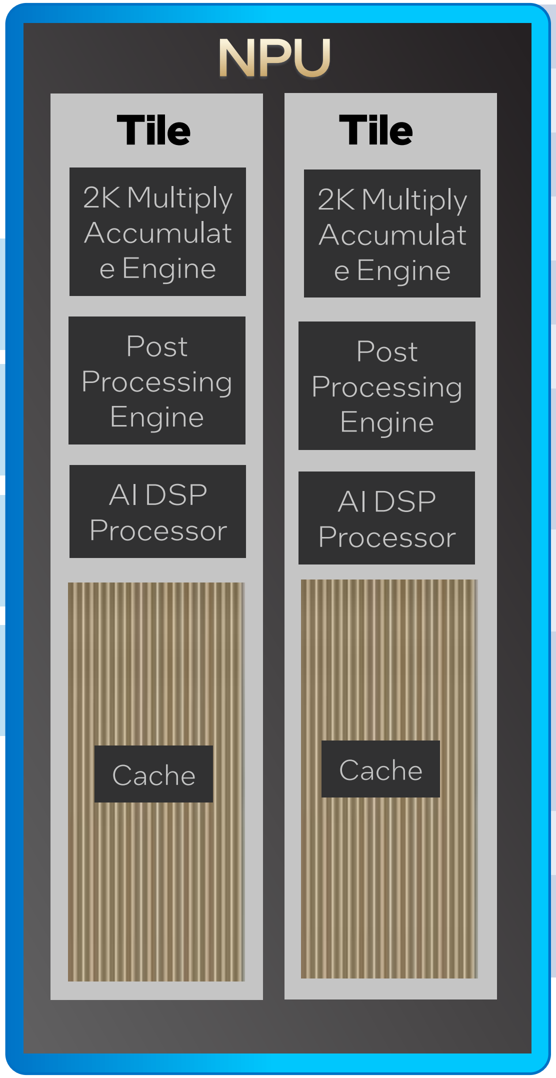
Power Efficient AI

Fast, Ultra Low Power Inferencing

Improve System and App Responsiveness

Reduce Memory I/O Usage

Drivers for Windows and Linux



NPU

Tile

2K Multiply Accumulate Engine

Post Processing Engine

AI DSP Processor

Cache

Tile

2K Multiply Accumulate Engine

Post Processing Engine

AI DSP Processor

Cache

Performance	Up to 13 TOPs (int8)
MAC Engine	4096 (INT8) with FP32 Accumulator
Local Cache	4096 KB Software-Managed
Programmable DSP	VLIW supporting Integer, FP, Transcendental
Peak Memory Interface BW	64 GBps, Unified Memory Architecture
Internal Data Type Support	INT8, FP16, BF16, FP32 (emulated)
Hardware Compression	Quantized Data Type Support Fine-Grain Weight and Activation Sparsity Weight Compression
MAC Fixed Function support	General Matrix-Matrix, Matrix-Vector Convolution, Fully Connected, Reshape
Elementwise Fixed Function support	ReLU/PReLU Add/Mul Quantize/Dequantize Reshape
OS Supported	Windows* OS, Chrome*, Linux*
Runtime Framework Support	OpenVINO™ Toolkit, ONNX RT, WinML/DirectML, WebNN

1. At Vmax in 15W MTL/ARL workload. Peak TOPs 13 at 1.6 GHz ResNet50, Int8, BS1, 50% sparsity
2. See backup for workloads and configurations. Results may vary.

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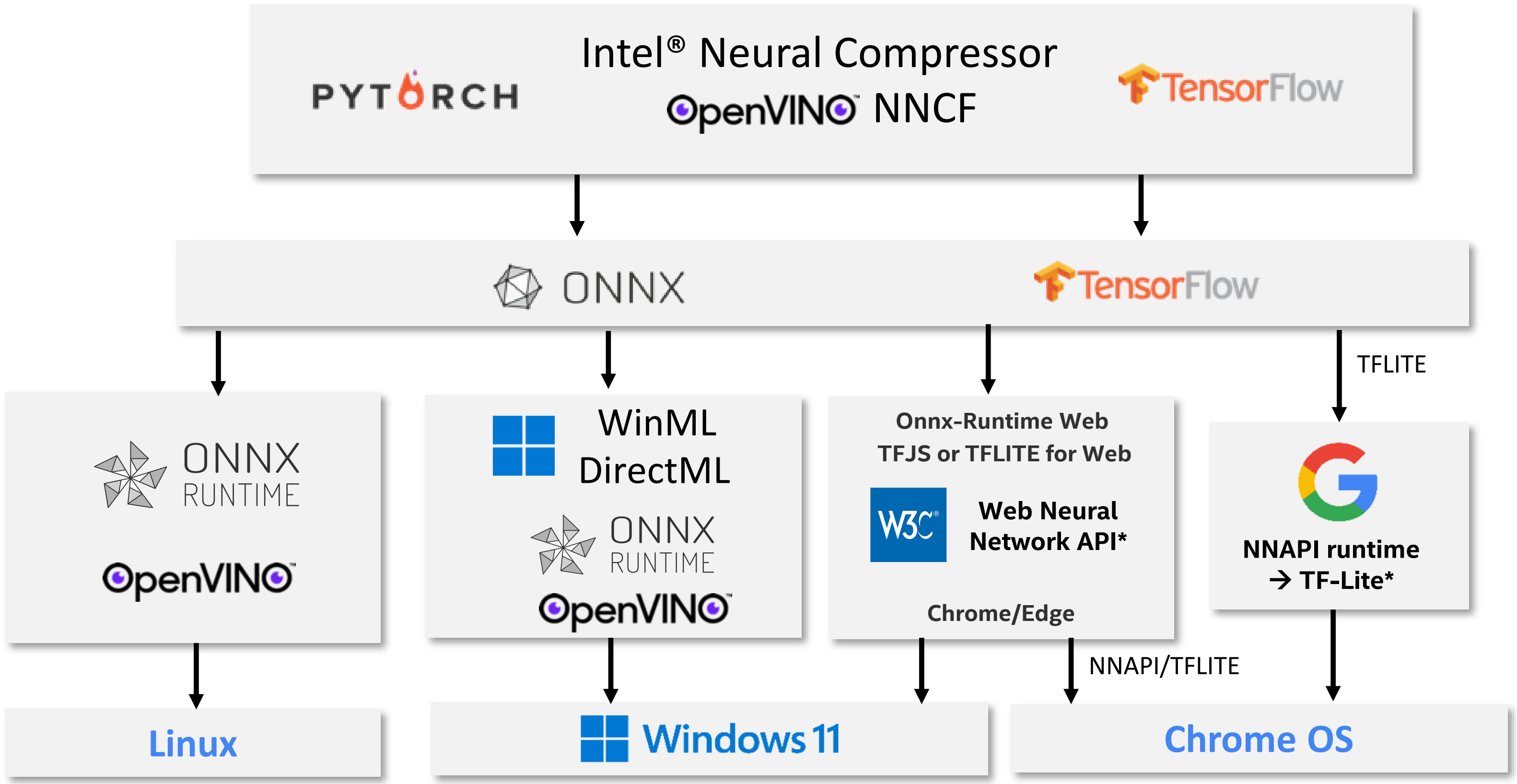
Software Frameworks for Innovation and Scale

Embracing and Enabling an Open Ecosystem



PYTORCH

Intel® Neural Compressor

OpenVINO NNCF

TensorFlow

ONNX

TensorFlow

ONNX RUNTIME

OpenVINO

WinML

DirectML

ONNX RUNTIME

OpenVINO

Onnx-Runtime Web

TFJS or TFLITE for Web

W3C Web Neural Network API*

Chrome/Edge

TFLITE

NNAPI runtime → TF-Lite*

NNAPI/TFLITE

Linux

Windows 11

Chrome OS

Training Frameworks / Tools

Model distribution formats

Inference Frameworks

Targeted Operating Systems

OpenVINO

Underlying technology ingredient and vertical option on Windows*/Linux*.

OpenVINO™ powers ONNX*-Runtime, Web, ChromeOS* interfaces.

Windows 11

Windows* ML + DirectML

ONNX-Runtime + OEM choice of EP (DirectML, MLAS, OpenVINO™)

NNAPI delegate for NPU

Consult OSV for any OEM differentiation opportunity

TensorFlow

PYTORCH

Native deployment support in evaluation, not on roadmap

NOT POR for GPU/NPU

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NPU Value Prop

Performance

To run advanced, higher quality AI models for Richer Experiences

Battery Life

Deliver premium AI based experiences without sacrificing battery life

Responsiveness

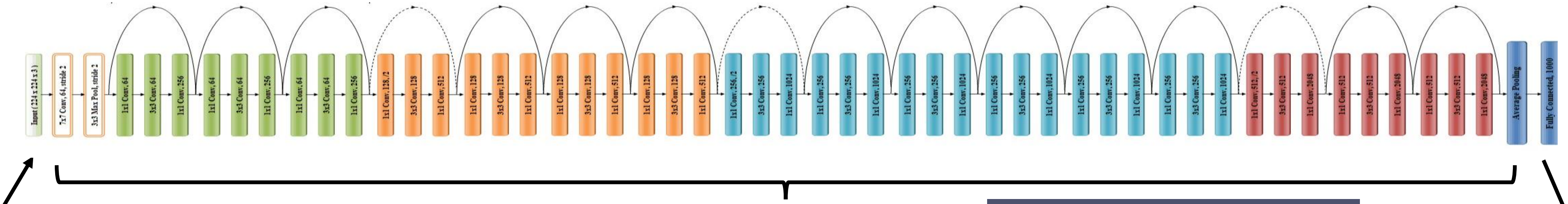
Free the CPU and iGPU for greater responsiveness & productivity

Workload's Good for the NPU:

Sustained AI Workloads	Offload the CPU, iGPU, dGPU for responsiveness	Require High integrated TOPs
Model Characteristics: small Batch Size, FP 16/Int8, Sparsity enabled models		
Image, Video, Audio		

Client AI - Todd Matsler

Resnet50 Example Based on MTL



Input 224x224

Workload
(MACs operations on NPU)

Output (frame)

- Peak TOPS (pTOPS) = Peak Theoretical Max Performance
  pTOPS = max frequency * (MAC/Clock) * 2

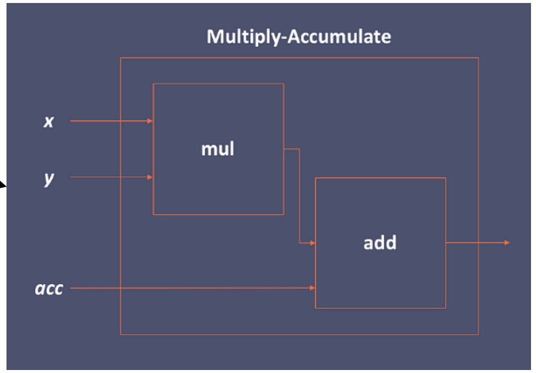
  <u>NPU is 11 pTOPS</u>

- Effective TOPS (eTOPS) = Real Performance on a given AI Workload (the efficiency of pTOPS)
  eTOPS = (fps * each frame GOPs)/1000

  <u>NPU 8.2 eTOPS = (1000 * 8.216)/1000</u>

- We use ResNet50: a common network + a good mix of a memory and compute bound network. Is it Perfect? -> No, but it is better than pTOPS as eTOPS shows real workload measured across many HW configs

- AI Benchmark for Client: Not 1 standard Today (UL Procyon Redowa (POR)/MLPerf/GeekBenchML)



One multiply-accumulate is two operations

- **Operations per frame: constant value per network, for Resnet50 it is 8.216 GOPs**

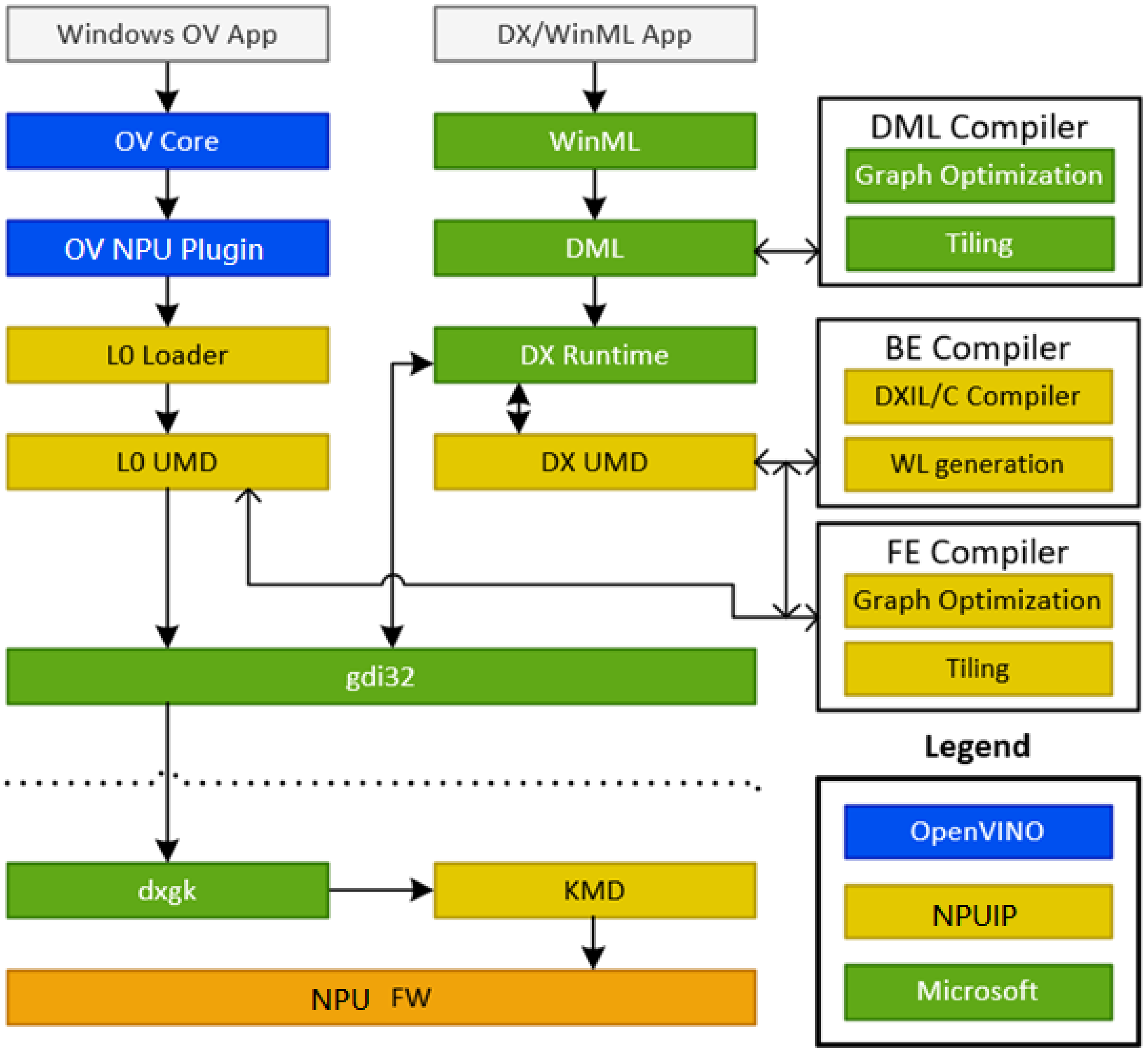
	pTOPS	ResNet50[3] fps	eTOPS	Efficiency
Intel MTL iVPU	11	Dense: 715[1] Sparse: 895[1] Sparse: 1000[2]	5.9[1] 7.3[1] 8.2[2]	53% 67% 75%
QCOM 8cx Gen3	20-25[4]	825	6.8	27-34%

[1] measured on early MTL Si & SW: B0 Si, pre-beta SW 2/3/2023
[2] with 50% sparsity enabled, estimated target for production Si and SW is ~1000fps & ~8.2 eTOPS
[3] MTL RN50: RN50 1.5 Open Model Zoo; QCOM RN50 version is UL Procyon AI Inference benchmark 2.4.0
[4] QCOM reports 29 pTOPS for 8cx Gen3 full SOC (CPU/GPU/NP); NPU only pTOPS estimated by Intel, based on current Intel internal analysis of available information

NPU OpenVINO™ Plus DirectML Stack

- Unified driver architecture using Microsoft* Compute Driver Model (MCDM)
- OpenVINO™ via Level 0 interface, WindowsML/DirectML via DX12
- DX12 UMD in NPU SW stack supports WindowsML/DirectML
- OpenVINO™ tools used to quantize/lower any ONNX* model for NPU execution
- OpenVINO™ Apps compile & execute models using NPU Compiler tool chain & L0 NPU driver
- DirectML use DML compiler plus NPU compiler tool chain and DX12 UMD
- The NPU Driver package includes NPU FW and Compilers to support JIT Compile

Windows* SW Stack



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What is MEP (Windows® Studio)?

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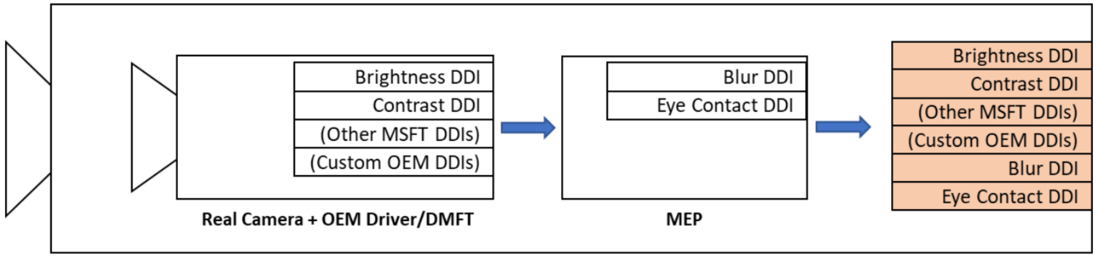
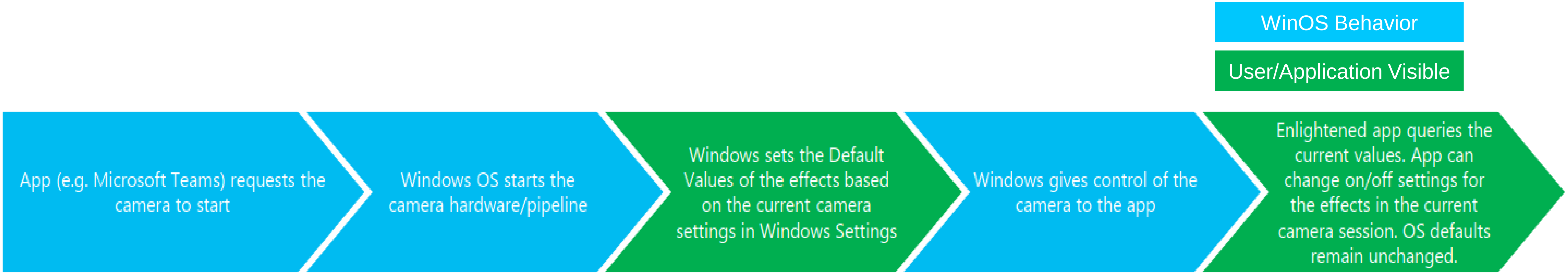
What is MEP?

Why Microsoft* Effect Pack?

- MEP standardized control interfaces (Camera DDIs and APIs)
- MSFT provide consistent AI Models:
  - Optimized Algorithm for NPU
  - OEM/ISV apps can apply effects to any camera



- MEP DDI Interface


WinOS Behavior

User/Application Visible

App (e.g. Microsoft Teams) requests the camera to start

Windows OS starts the camera hardware/pipeline

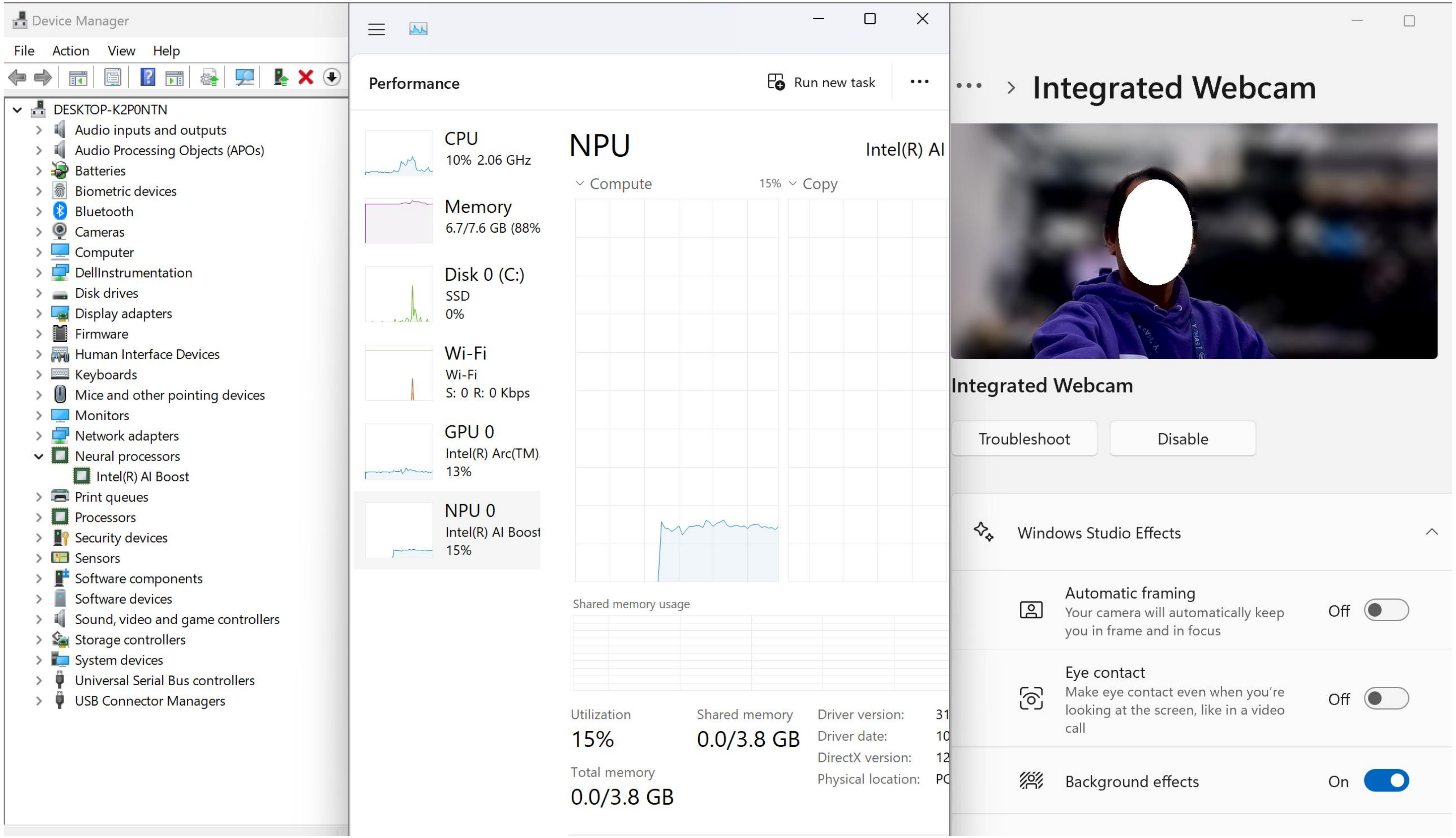
Windows sets the Default Values of the effects based on the current camera settings in Windows Settings

Windows gives control of the camera to the app

Enlightened app queries the current values. App can change on/off settings for the effects in the current camera session. OS defaults remain unchanged.

- Example: Configurable MEP effects by Application

Intel® NPU (NPU) Running Windows* Studio (MEP)



Device Manager

File Action View Help

- DESKTOP-K2P0NTN
  - Audio inputs and outputs
  - Audio Processing Objects (APOs)
  - Batteries
  - Biometric devices
  - Bluetooth
  - Cameras
  - Computer
  - DellInstrumentation
  - Disk drives
  - Display adapters
  - Firmware
  - Human Interface Devices
  - Keyboards
  - Mice and other pointing devices
  - Monitors
  - Network adapters
  - Neural processors
    - Intel(R) AI Boost
  - Print queues
  - Processors
  - Security devices
  - Sensors
  - Software components
  - Software devices
  - Sound, video and game controllers
  - Storage controllers
  - System devices
  - Universal Serial Bus controllers
  - USB Connector Managers

Performance

Run new task

CPU
10% 2.06 GHz

Memory
6.7/7.6 GB (88%

Disk 0 (C:)
SSD
0%

Wi-Fi
Wi-Fi
S: 0 R: 0 Kbps

GPU 0
Intel(R) Arc(TM)
13%

NPU 0
Intel(R) AI Boost
15%

NPU Intel(R) AI

Compute 15% Copy

Shared memory usage

Utilization
15%

Shared memory
0.0/3.8 GB

Total memory
0.0/3.8 GB

Driver version: 31
Driver date: 10
DirectX version: 12
Physical location: PC

Integrated Webcam

Integrated Webcam

Troubleshoot Disable

Windows Studio Effects

Automatic framing
Your camera will automatically keep you in frame and in focus
Off

Eye contact
Make eye contact even when you're looking at the screen, like in a video call
Off

Background effects
On

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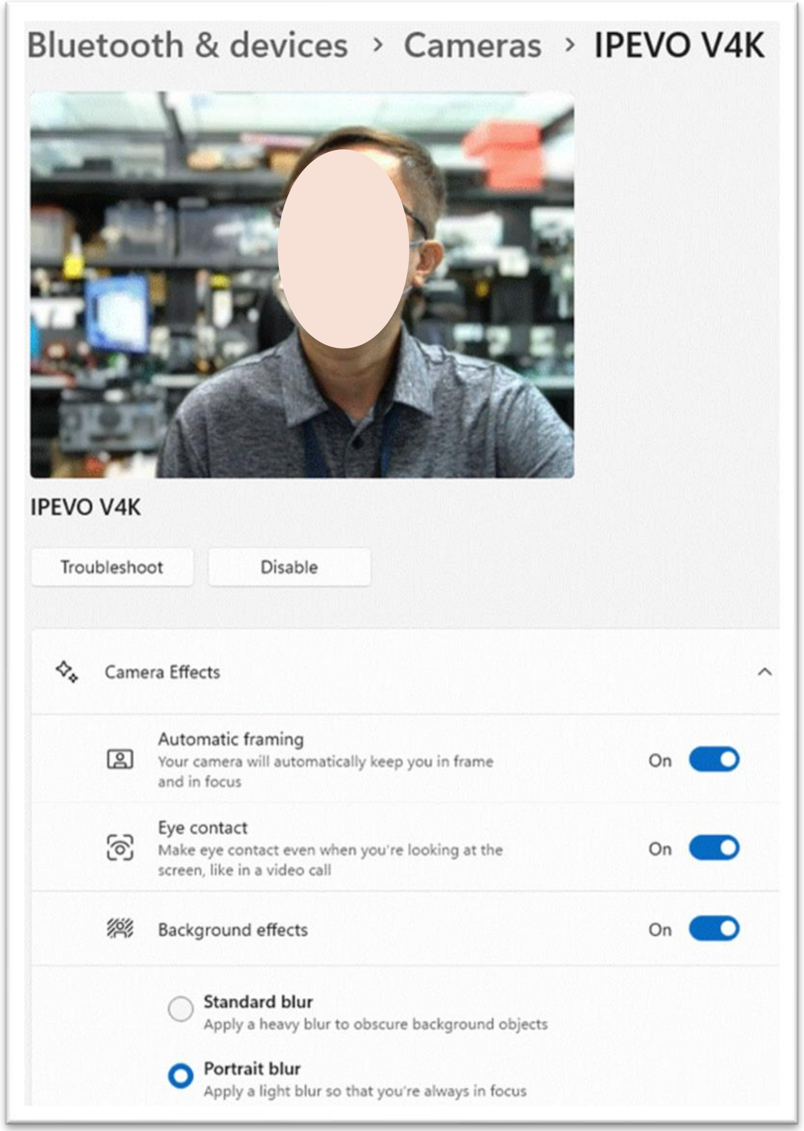
Windows* Settings Camera Page and Inbox Camera Application



Bluetooth & devices › Cameras › **IPEVO V4K**

IPEVO V4K

Camera Effects

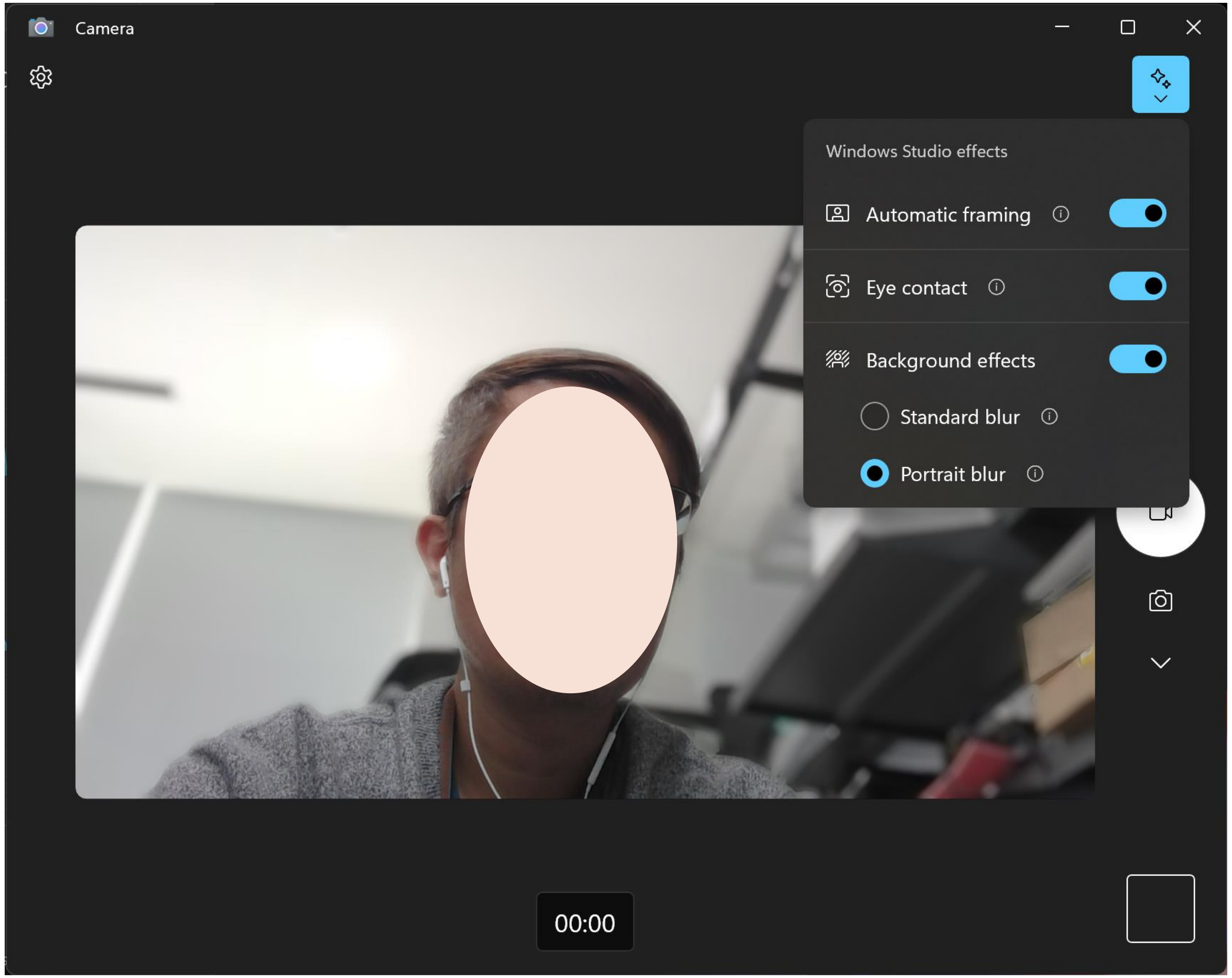
Automatic framing
Your camera will automatically keep you in frame and in focus
On

Eye contact
Make eye contact even when you're looking at the screen, like in a video call
On

Background effects
On

○ **Standard blur**
Apply a heavy blur to obscure background objects

● **Portrait blur**
Apply a light blur so that you're always in focus



Windows Studio effects

Automatic framing: On

Eye contact: On

Background effects: On

○ Standard blur

● Portrait blur

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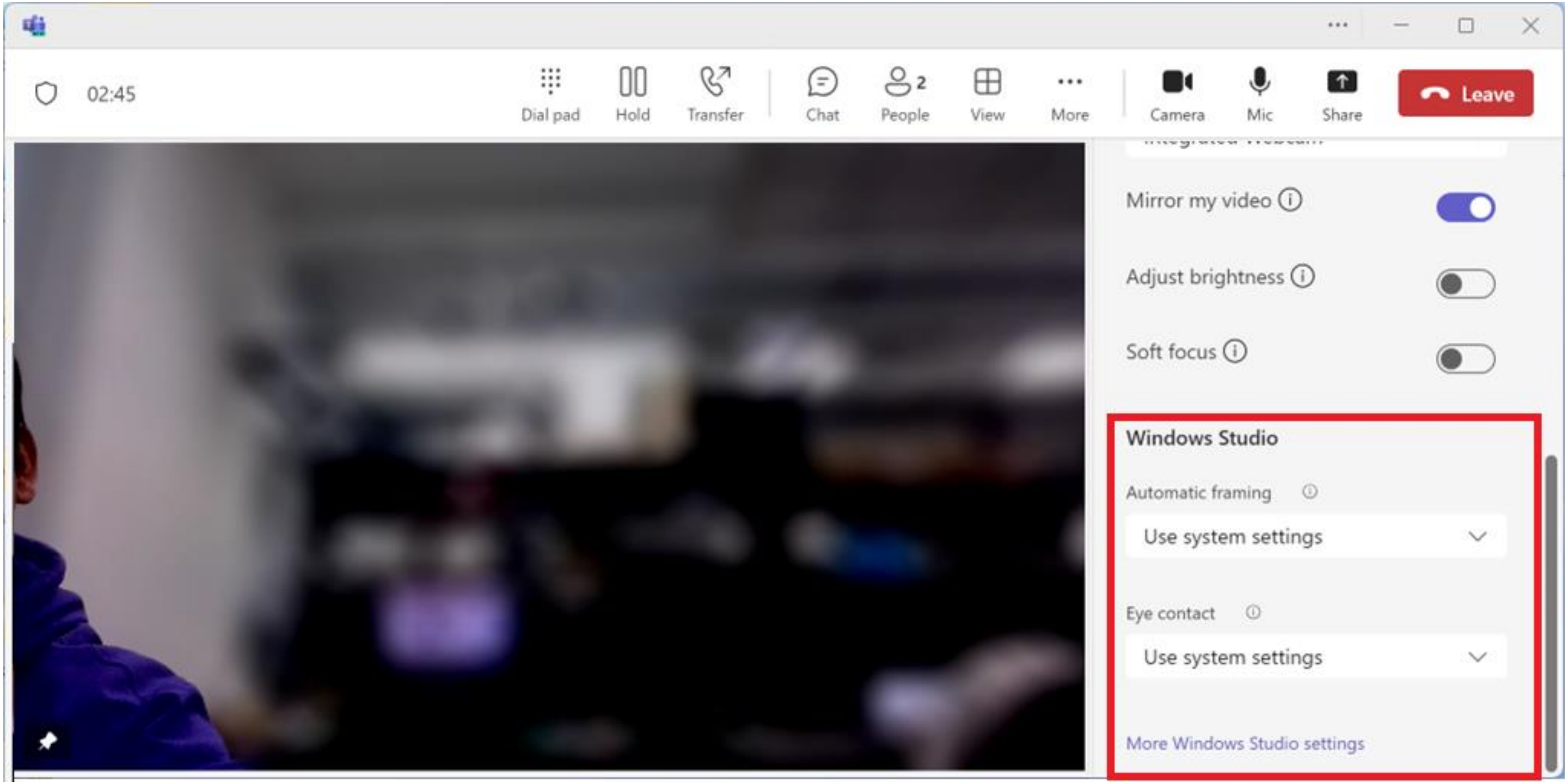
New TEAMS* – Settings Page



Mirror my video ⓘ ●

Adjust brightness ⓘ ○

Soft focus ⓘ ○

Windows Studio

Automatic framing ⓘ

Use system settings

Eye contact ⓘ

Use system settings

More Windows Studio settings

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ARL NPU POR Features

ARL NPU POR Features – MEP + APO

MEP (Windows* Studio Effects)	ARL NPU
Background Blur	NPU
Bokeh	NPU
Eye Contact Correction	NPU
Voice Focus*	CPU
Auto Framing	NPU
Voice access/ Live caption	NPU
More.. (TBD)	NPU

+

APO Vendor	
Realtek	NPU
Waves	NPU
Elevoc	NPU
Dolby	NPU
Fortemedia	NPU
Intelligo	NPU

Notes:

- Intel will work with Microsoft* to evaluate future capabilities for ARL and beyond
- Customers should contact Microsoft* to discuss MEP feature roadmap
- APO depends on OEM choice and optimization with Intel
- For "Voice Focus", it is CPU only for now. NPU is TBD.

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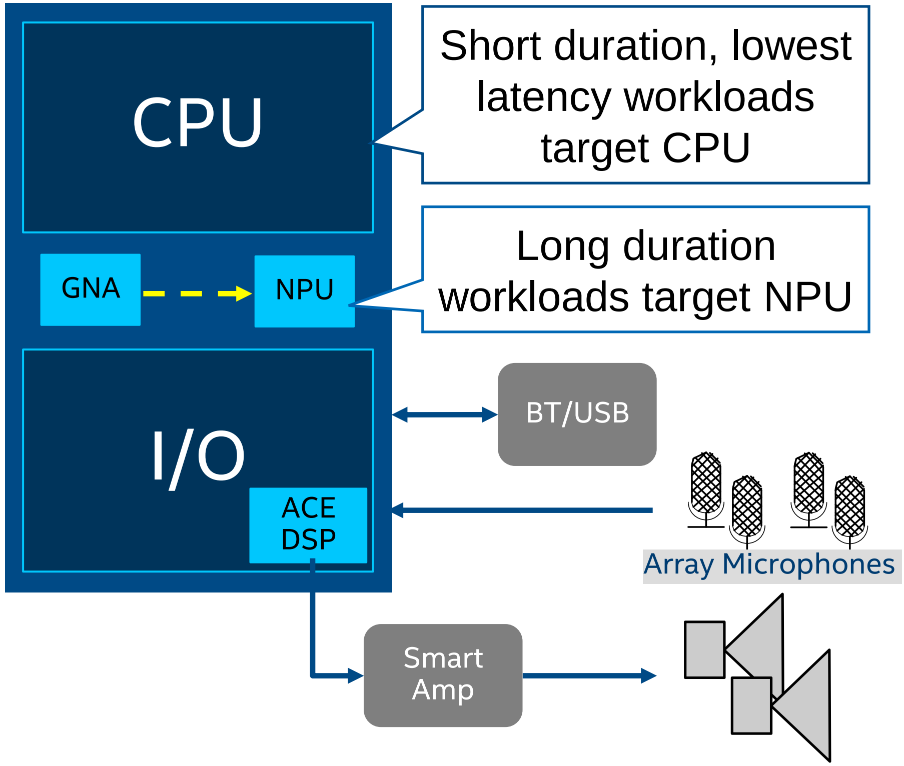
ARL APO

Audio AI Offload Transitions to NPU

TGL-MTL platforms include GNA for offloading Dynamic Noise Suppression (DNS) from CPU.

- DNS and other audio AI workloads (example: ASR) will migrate to NPU
- Migration starts on MTL, completes on LNL (no GNA)
- Most S0 audio processing will run on either NPU or CPU
- Post processing of audio playback runs on a DSP


CPU
GNA
NPU
I/O
ACE DSP
Short duration, lowest latency workloads target CPU
Long duration workloads target NPU
BT/USB
Array Microphones
Smart Amp

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APO – Audio Processing Object

- Windows* allow OEMs and third-party audio hardware manufacturers to include custom digital signal processing effects as part of their audio driver's value-added features. These effects are packaged as user-mode system effect Audio Processing Objects (APOs).
- Audio processing objects (APOs), provide software based digital signal processing for Windows* audio streams. An APO is a COM host object that contains an algorithm that is written to provide a specific Digital Signal Processing (DSP) effect.
- Examples of APOs include graphic equalizers, reverb, tremolo, Acoustic Echo Cancellation (AEC) and Automatic Gain Control (AGC). APOs are COM-based, real-time, in-process objects.

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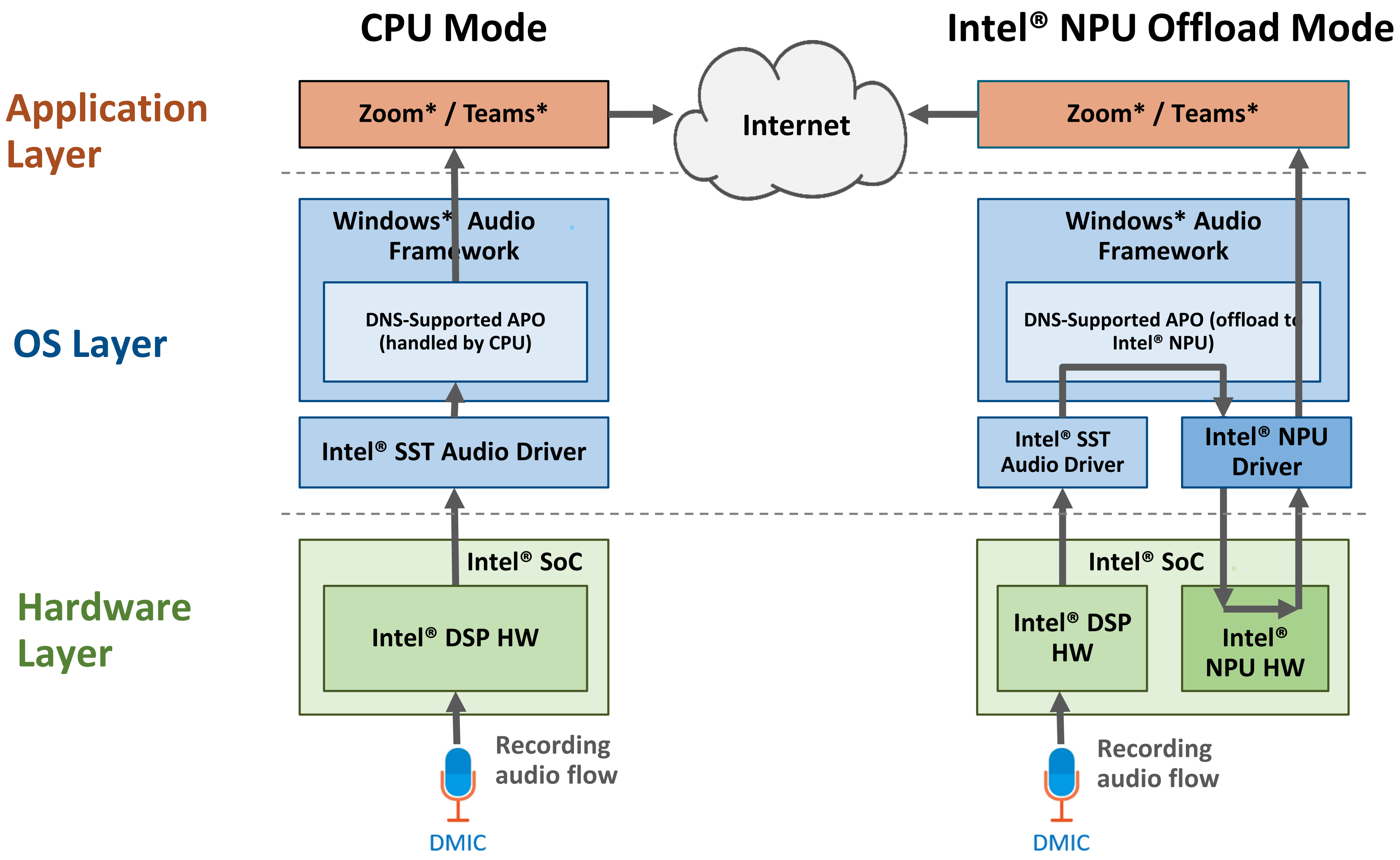
Audio Flow with Intel® NPU DNS



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NPU Software Enabling and Experience

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Meteor Lake ISV AI Moments

Q4 '23

OCT NOV DEC

Intel Client AI Industry Enabling

Cisco webex, zoom, GIMP, 腾讯会议 Tencent Meeting, QQ, AUTODESK, Microsoft Teams, chaos, Google Meet, TOPAZ LABS, iQIYI, Office, HandBrake, blender, Adobe, Blackmagicdesign, CyberLink, wondershare, XSplit, WAVES, Tencent Video, ByteDance 字节跳动, Alludo, SKYLUM, Microsoft Defender for Endpoint, ELEVOC, MAGIX, fortemedia, intelliGo Technology Inc., krisp, REALTEK, CROWDSTRIKE, Open Broadcaster Software, Figma, Khan Academy, AVID

Meteor Lake Launch Event

- Rewind
- Adobe
- Microsoft MEP
- Microsoft Teams
- Windows Accessibility
- Gimp
- Xsplit
- Audacity
- OBS
- iQiYi
- Wondershare
- ByteDance
- BufferZone

Cisco WebEx One

- WebEx (AI tech preview)

Q1 '24

JAN FEB MAR

CES Platform Launch

- Zoom
- Crowdstrike
- Magix
- Cyberlink
- Skylum
- VMware WS1

BETT (Edu) Platform Launch

- Microsoft MEP
- Teams
- Zoom
- Windows
- Adobe
- Google Meet
- Labster
- VictoryXR

Commercial Launch

- Office & Co-Pilot
- Adobe
- Microsoft Defender
- Crowdstrike
- Zoom
- Teams
- Cisco Webex
- Tencent Meeting
- Autodesk
- Google Meet
- Figma
- GoTo Technologies
- Ivanti

Investor Day

- Khan Academy
- Adobe
- Gimp – Stable Diff
- Zoom
- Teams
- Cisco Webex
- Crowdstrike
- Autodesk

Q2 '24

APR MAY JUN

RSA Security Event

- Defender
- Trend Micro
- BitDefender
- CrowdStrike
- BufferZone
- Trellix
- Sophos

Intel Vision Series: AMR, EMEA, APJ/PRC

- Regional ISVs & Solution Partners
- Future AI use cases

Microsoft Build

- Adobe
- Microsoft Teams

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NPU Software Enabling

- Microsoft* Collaboration:
  - Windows* Studio Effects, OS Accessibility, and New OS Experiences
  - 1st party App AI experiences: Office and Teams
  - Co-engineering DirectML for NPU – for broader scale
    - Supports ONNX Runtime DML-EP
- Industry-standard Software Framework Support for Broad, Open ISV Application Ecosystem
- Enablement of Select OEM Proprietary Models

ISV Partner Targets (not a POR). List Not Exhaustive.

Microsoft

zoom, Adobe, TOPAZ LABS, XSplit, Dolby, MAGIX

Office, Google Meet, Tencent, OBS OPEN BROADCASTER SOFTWARE, CyberLink, blender, ByteDance, GIMP, Audacity

"Microsoft believes that neural processing units, like Intel's NPU, represent an inflection point in computing and will be key to delivering a whole new range of delightful experiences to Windows users on their PCs. These experiences will transform how people use their computers and connect with others. We are closely partnering with Intel on NPU and are excited to share more soon." - Vivek Pradeep, Partner Research Manager, Microsoft

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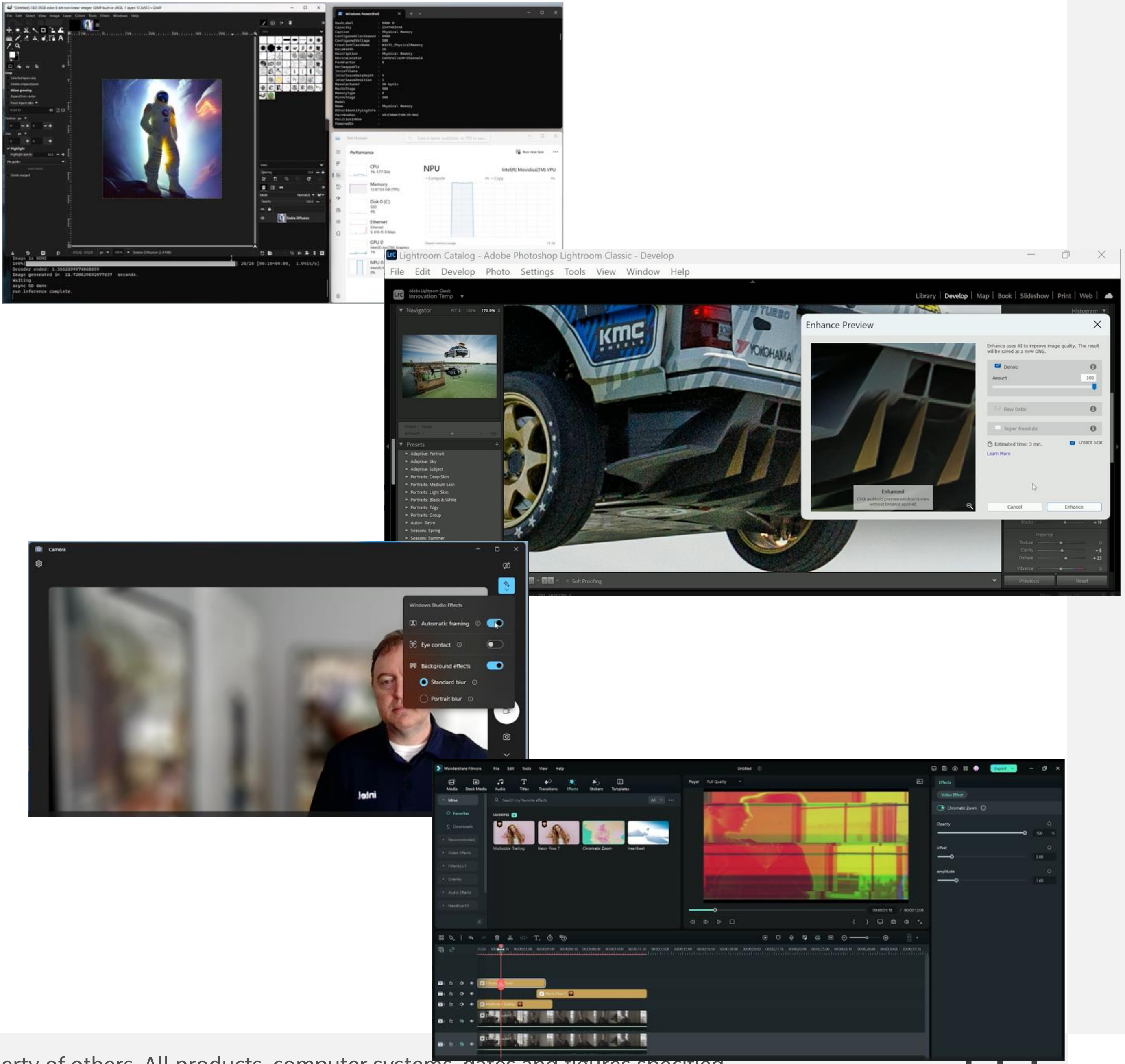
AI Workload Briefcase

- Visit AI Workload Briefcase,
  - Videos Reference:
    - GIMP with Stable Diffusion
    - Adobe Lightroom Classic AI Photo Editing
    - AI Enhanced Collaboration with Windows Studio Effects
    - Wondershare Filmora: AI Video Editing
  - Workload Assets:
    - GIMP with Stable Diffusion
    - Adobe Lightroom Classic AI Photo Editing
    - XSplit VCam NPU Background Segmentation
  - Etc.

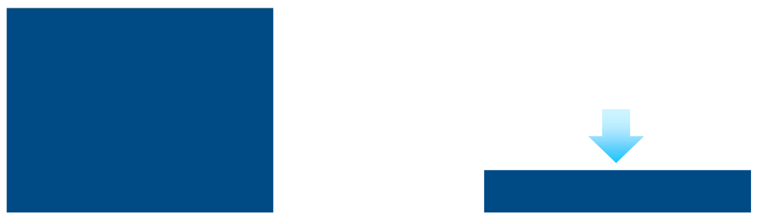

Performance
CPU
NPU
Memory
Lightroom Catalog - Adobe Photoshop Lightroom Classic - Develop
File Edit Develop Photo Settings Tools View Window Help
Library | Develop | Map | Book | Slideshow | Print | Web
Navigator
Presets
Enhance Preview
Cancel
Enhance
Camera
Windows Studio Effects
Automatic framing
Eye contact
Background effects
Standard blur
Portrait blur

Enhanced Collaboration Experiences

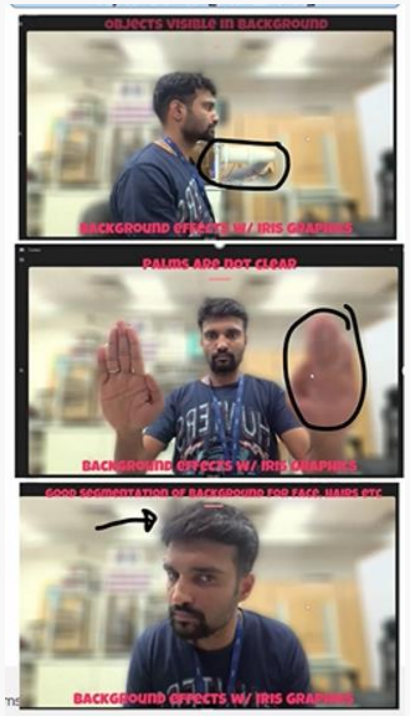
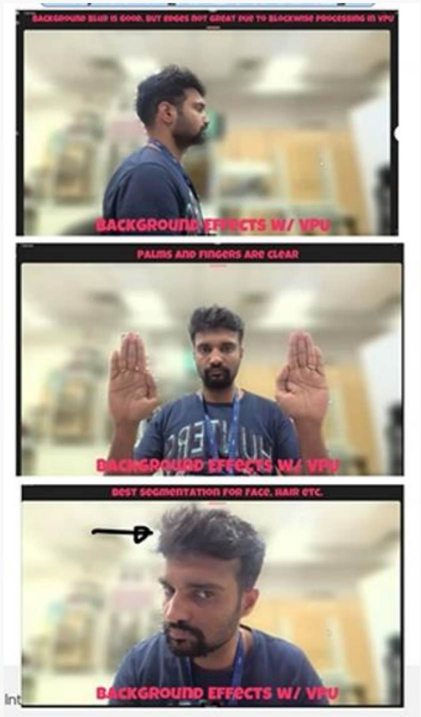
New and improved features

New!	Improved!
Auto-framing Eye contact Avatar representation Gesture recognition	Background Concealment Dynamic Noise Suppression

CPU Workload



Advanced Blur

Basic Blur	Advanced Blur
	

OBJECTS VISIBLE IN BACKGROUND
BACKGROUND EFFECTS W/ IRIS GRAPHICS
PALMS ARE NOT CLEAR
BACKGROUND EFFECTS W/ IRIS GRAPHICS
GOOD SEGMENTATION OF BACKGROUND FOR FACE, HAIRS ETC
BACKGROUND EFFECTS W/ IRIS GRAPHICS

BACKGROUND BLUR IS GOOD, BUT EDGES NOT GREAT DUE TO BLOCKWISE PROCESSING IN VPU
BACKGROUND EFFECTS W/ VPU
PALMS AND FINGERS ARE CLEAR
BACKGROUND EFFECTS W/ VPU
BEST SEGMENTATION FOR FACE, HAIR ETC.
BACKGROUND EFFECTS W/ VPU

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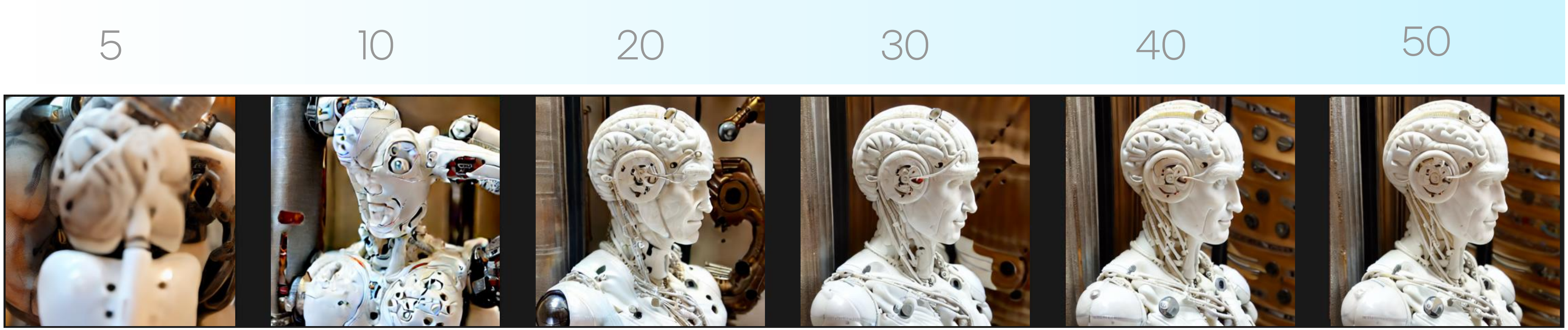
Generative AI Experiences

Open-source GIMP plug-in for Stable Diffusion at Performance



Text Prompt: cyborg man with a highly detailed, intricate details, carved by Michelangelo

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Seeding Open-Source Projects

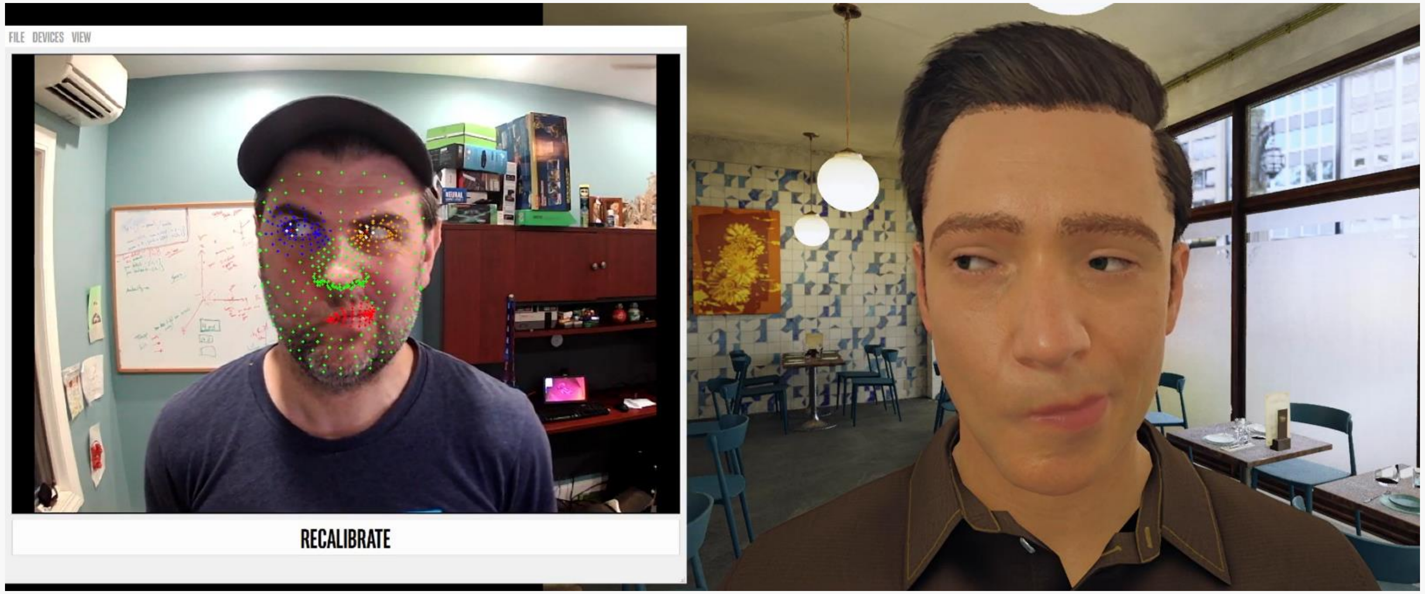
blender

Audacity

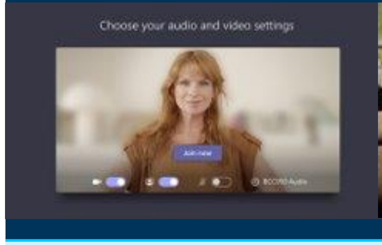
Open Broadcaster Software

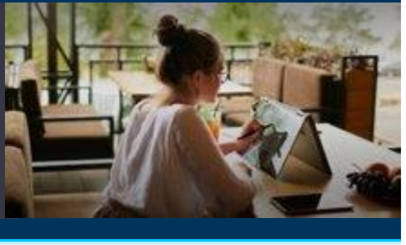
Realtime motion capture for Unreal Engine

Maintain/improve render performance on the GPU by offloading the AI to the NPU



Transforming the PC Experience





AI Today

Enhancements

Elevated video collaboration & streaming
Enhanced Audio effects
Creator and Gaming effects

AI Tomorrow

Everything

AI Assistants know your daily context
More creative, productive, & collaborative
Across everything you do

Cloud

Massive scalable compute
High Latency
Privacy Concerns
Expensive

Client

Massive distributed scale
Low Latency
Improved Privacy
Lower Cost (to ISV)

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