Vision with Precision Webinar Series

Augmented & Virtual Reality

Aaron Behman, Xilinx

Mark Beccue, Tractica

Xilinx Vision with Precision Webinar Series

❯ Perceiving Environment / Taking Action: AR / VR

❯ Monitoring Things

- *Machine Vision*
- *Surveillance*
- *Medical Imaging*

Drones & VGR	ADAS	AR / VR

Differentiate by Design

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Agenda

- o Embedded Vision Market Trends

- o AR / VR Technology Trends

- o Tractica's Perspective

- o AR / VR Solutions

- o Q&A

Enabling Embedded Vision

ADAS, Machine Vision, Surveillance, Drones, Medical, AR/VR, Displays…

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Rapid Growth of Vision Systems

Vision System Shipments

$ Billions

Source: Synopsys, consolidated from multiple sources

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Embedded Vision Applications

Embedded Vision

Automotive

- Front Cameras
- Machine Learning
- Surround View
- AR in HUDs
- Driver / Passenger Monitoring

ISM

- Industrial AR
- Surveillance
- Robotics
- Inspection & Detection
- Medical Diagnostics

A&D, AVB, Consumer

- Military ISR & AR
- Guidance Systems
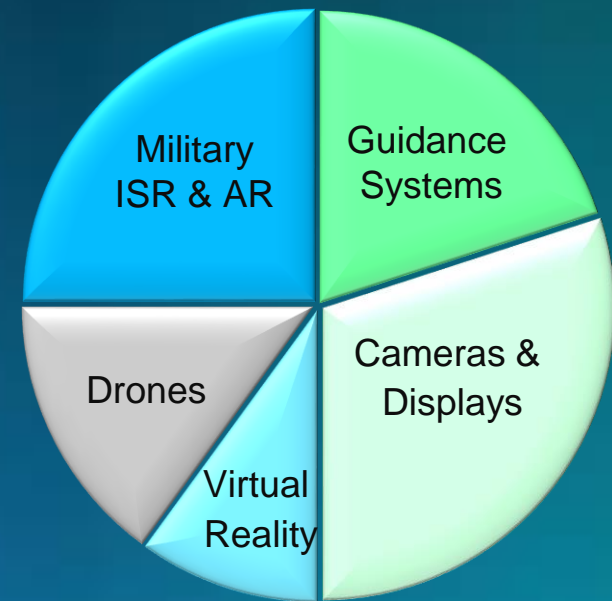- Cameras & Displays
- Drones
- Virtual Reality

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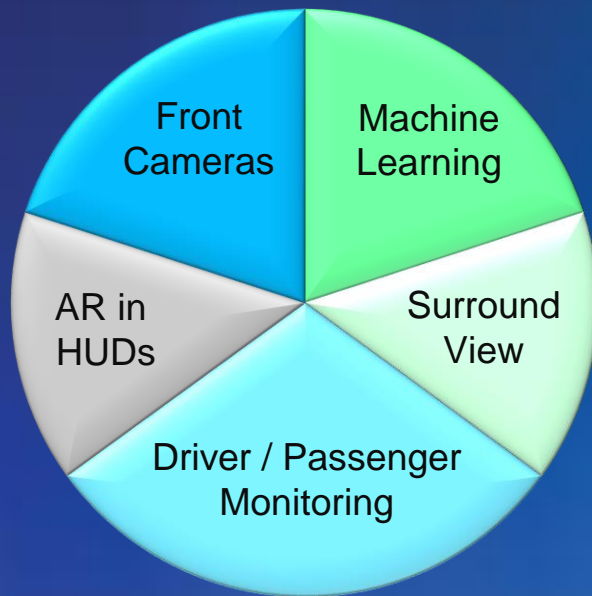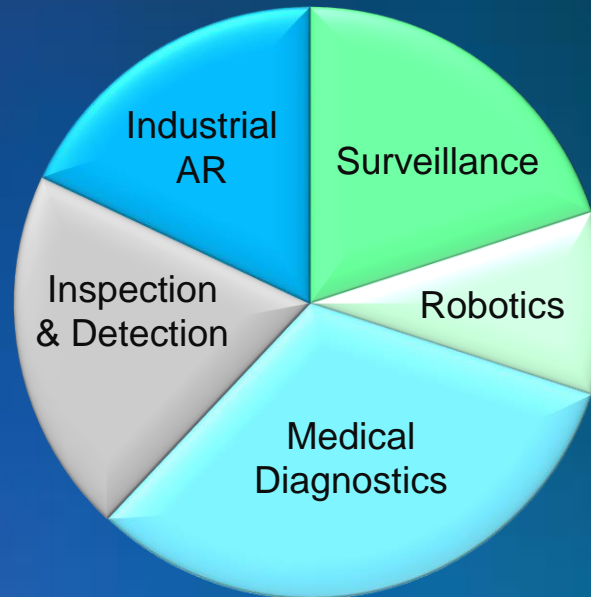
>200 Vision Customers Powered by Xilinx

POWERED
BY XILINX

Camera
>30 Camera Brands

ADAS
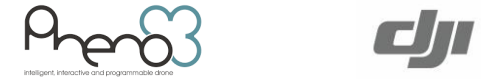23 Auto Makers, 85 Models

Industrial
>50 Equipment Manufacturers

Broadcast
8 Major Broadcasters

ProAV
>70 Equipment Makers

Drones
>5 Drone Companies

VR/AR
8 VR/AR Companies

Medical
>10 Medical Companies

Display
>30 Major Brands

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Embedded Vision
Momentum

24 Million, 3X
ADAS Unit Shipments, Increase (2 Years)

>80
2016/17 Auto Models Shipping ADAS w/ Xilinx

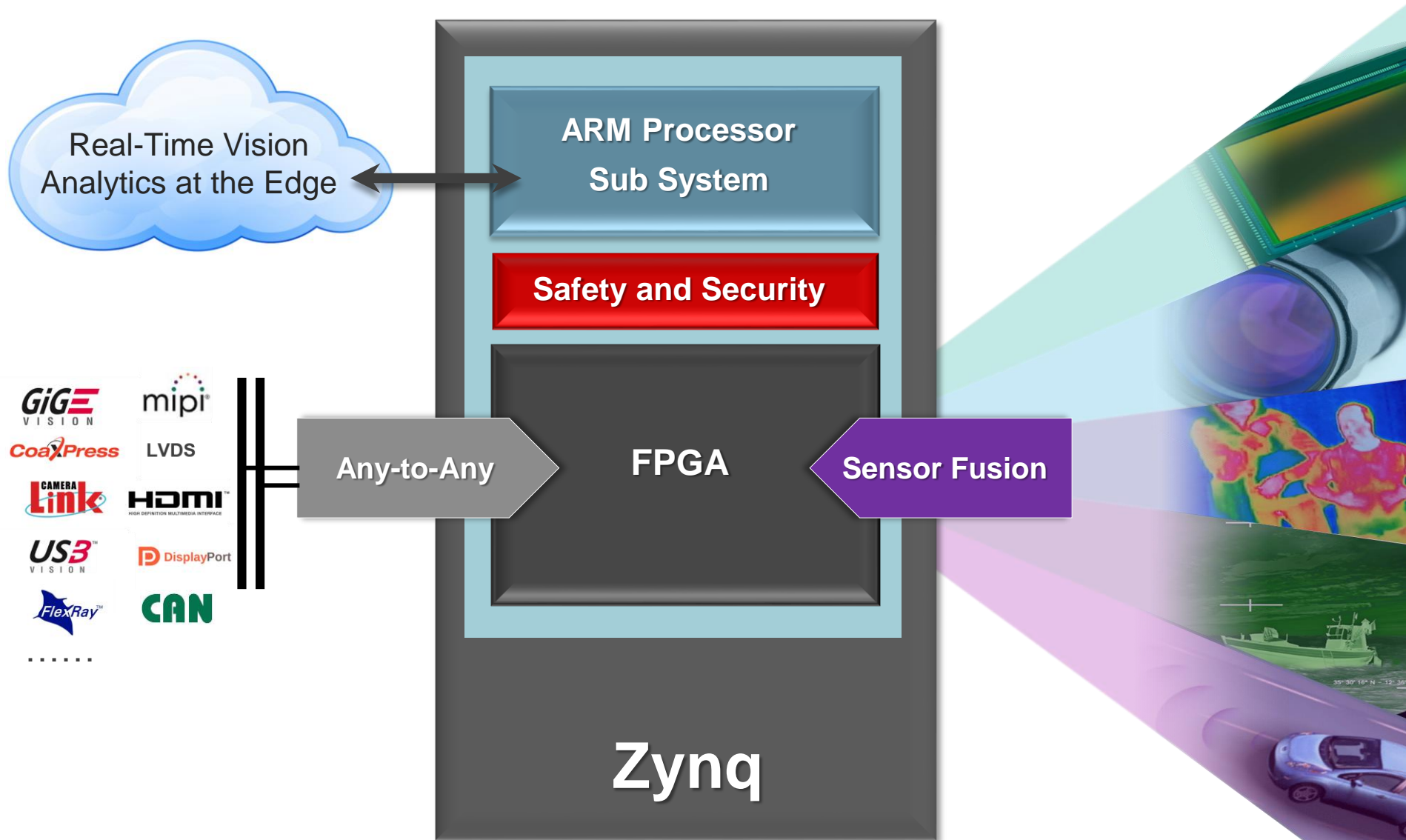**>200**
Customers Delivering Vision with Xilinx

$100B to $350B
5 Yr Growth of Vision System Shipments

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Best Platform for Embedded Vision

Real-Time Vision Analytics at the Edge

ARM Processor Sub System

Safety and Security

FPGA

Any-to-Any

Sensor Fusion

GiGE VISION

mipi

CoaXPress

LVDS

CAMERA Link

HDMI HIGH DEFINITION MULTIMEDIA INTERFACE

USB VISION

DisplayPort

FlexRay

CAN

......

Zynq

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5 Differentiating Advantages
"Vision with Precision"

Vision and ADAS

1 Real-time Image Recognition and Analytics

2 All Programmable Platform Reuse

3 Scalable Sensor Fusion

4 Highest Performance/Watt

5 Only Single Chip Safety and Security

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AR / VR

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Virtual vs. Augmented vs. Mixed Reality

Composite image by Re/code; original: Japanexperterna.se

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Virtual vs. Augmented vs. Mixed Reality

Market Projections VR - Consumer

Annual VR Hardware Unit Shipments by Product Type, World Markets: 2014-2020

Legend:
- Vests and Suits
- Locomotion Devices
- Hand Tracking Devices
- Gamepads and VR-Specific Controllers
- Head-Mounted Displays

Annual HMD Unit Shipments by Product Type, World Markets: 2014-2020

Legend:
- Mobile VR Headsets
- Console-Based HMDs
- PC-Based HMDs
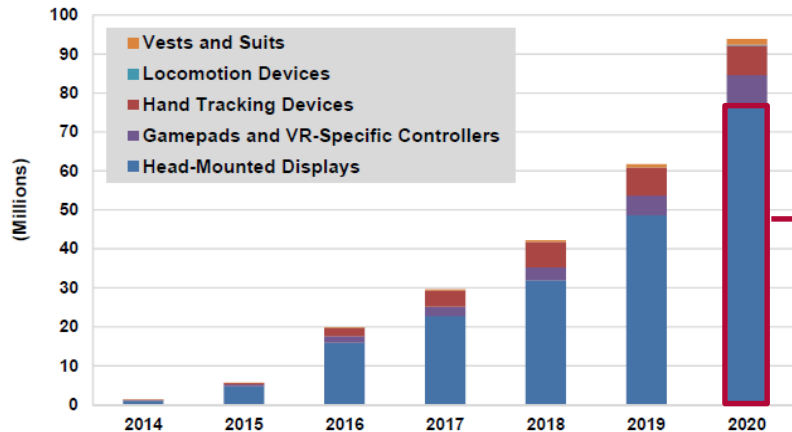
> ~ $8B market by 2020

> ~ 28% CAGR$^{2016\text{-}2020}$
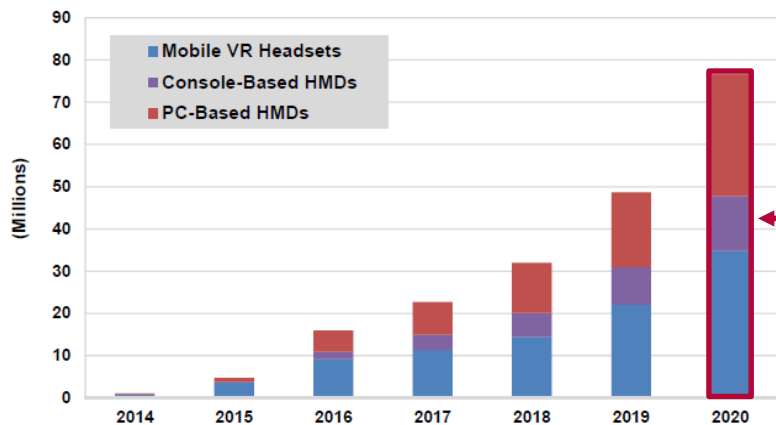
> Head-Mounted largest category
  – Mobile/Embedded largest category

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Market Projections VR - Enterprise

Annual VR Hardware Revenue by Product Type, World Markets: 2014-2020

Legend:
- Head-Mounted Displays
- Motion Capture Cameras
- Displays and Projectors
- Hand Tracking Devices
- Locomotion Devices

($ Thousands)

Values: $2,500,000 / $2,000,000 / $1,500,000 / $1,000,000 / $500,000 / $0

Years: 2014, 2015, 2016, 2017, 2018, 2019, 2020

(Source: Tractica)

Annual VR Hardware Unit Shipments by Product Type, World Markets: 2014-2020

Legend:
- Head-Mounted Displays
- Motion Capture Cameras
- Displays and Projectors
- Hand Tracking Devices
- Locomotion Devices

(Thousands)

Values: 600 / 500 / 400 / 300 / 200 / 100 / 0

Years: 2014, 2015, 2016, 2017, 2018, 2019, 2020

(Source: Tractica)

> Enterprise to reach nearly $2.5B '20

> Growing faster than consumer

> Content & creation tools as large as the equipment market

> Head-Mounted largest category

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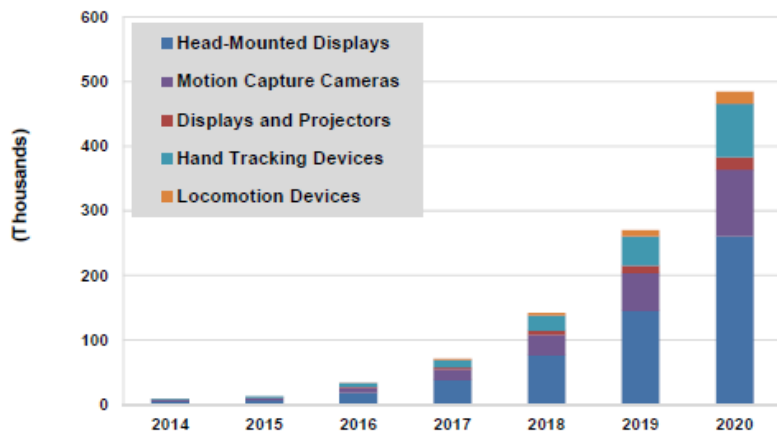
Market Projections – Augmented Reality

Smart AR Glasses Device Revenue, World Markets: 2013-2020

Smart AR Glasses Shipments, World Markets: 2013-2020
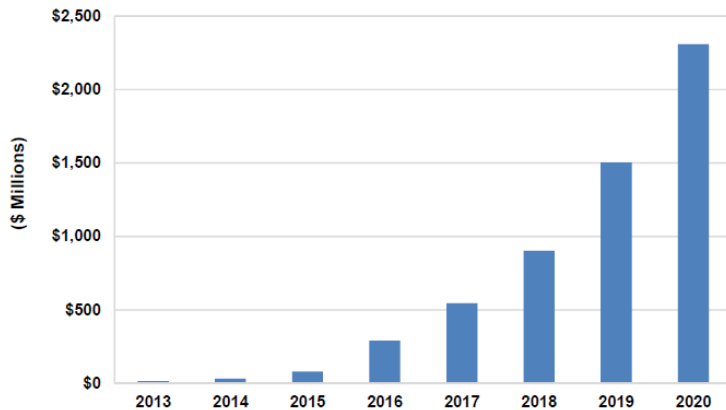
- Fast growing category
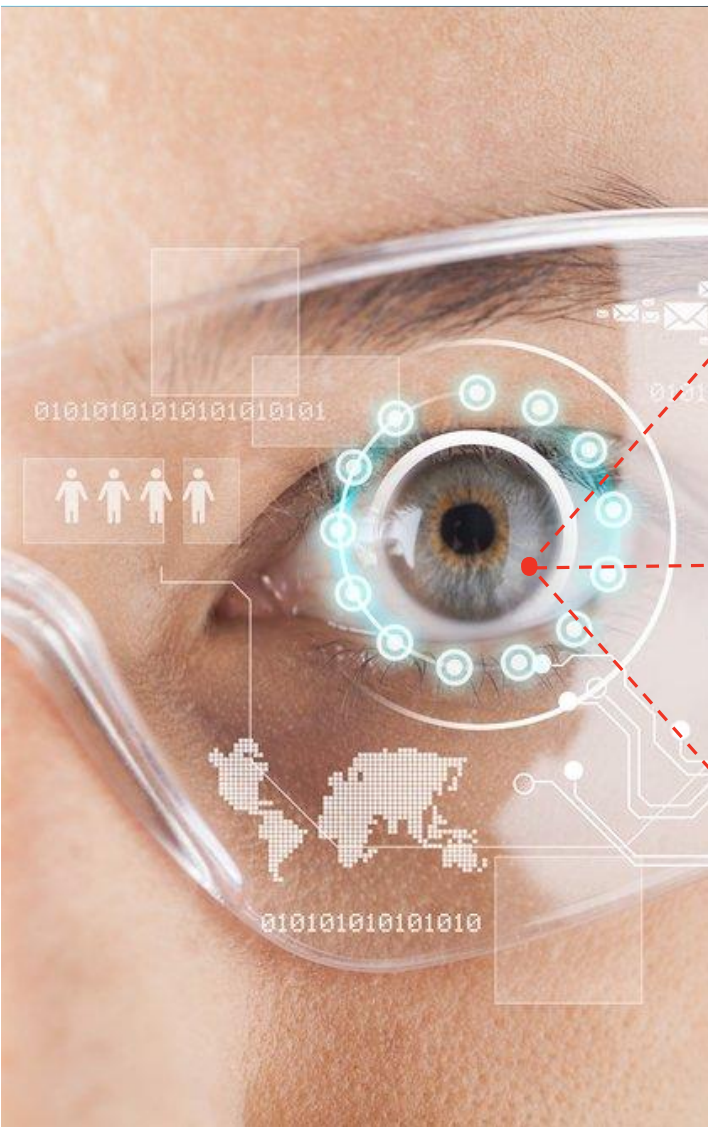- Approaching $2.5B in revenue by 2020
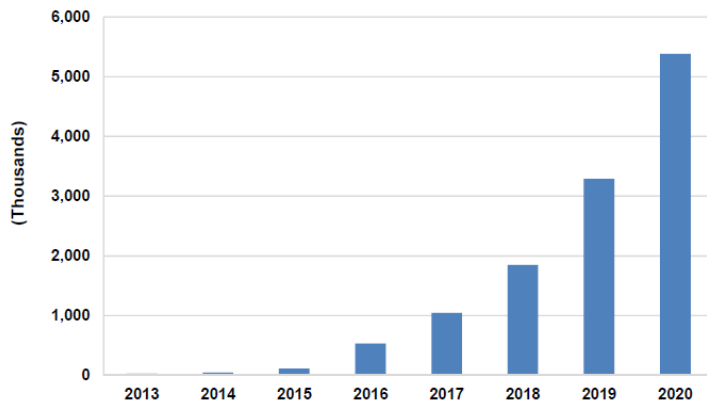
- Much larger volume than VR

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Markets and Applications

HUD in Vehicle • Factory Maintenance • Content Capture
Situational Awareness / ISR • **Drone Perspective** • Medical/Surgical

Enabling Smarter AR / VR Systems

- Multi-Sensor Fusion

- Real-Time Intelligence

- Compute at the Edge

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Differentiating Advantages in AR / VR

5 Differentiating Advantages
"Vision with Precision"

Vision and ADAS

1. Real-time Image Recognition and Analytics ✓
2. All Programmable Platform Reuse
3. Scalable Sensor Fusion ✓
4. Highest Performance/Watt ✓
5. Only Single Chip Safety and Security ✓

- Very high frame rate, recognition and analytics enabled through massive parallelism
- Scalable *sensor fusion* supports stereo to N vision pipelines + different sensor types
- Most computationally productive platform enabling highest performance per Watt
- ARM TrustZone & TRUST compliance for anti-tamper and information assurance

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TECHNOLOGY TRENDS IN AR / VR

Multi Camera Vision
- **Complete perspective with surround view**
- **Diverse sensor modalities provide enhanced vision**
- **Processing performance can now support dense fusion**
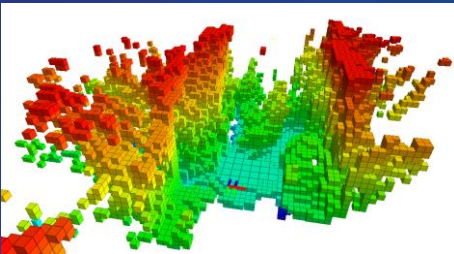
Computer Vision (CV) Techniques
- **OpenCV/OpenVX libraries increase productivity**
- **Optical Flow provides enhanced motion detection**
- **3D/Stereo Vision enhances depth perception**
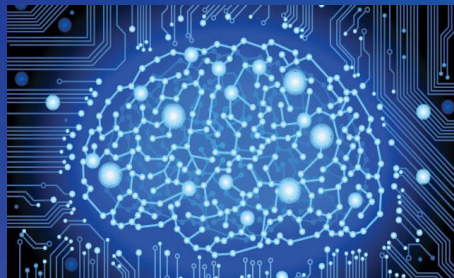
Machine Learning Techniques → Building on CV
- **Promises better recognition capability**
- **Object Detection & Classification thru Neural Networks**
- **Includes Convolutional, Deep and Recursive Neural Nets**

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The Machine Learning Dichotomy

Training

Photo: NVIDIA

- ❯ How the model is formed and developed
- ❯ Many approaches: DNN, CNN, RNN
- ❯ Low volume application requiring HPC
- ❯ DPfpu required to build models

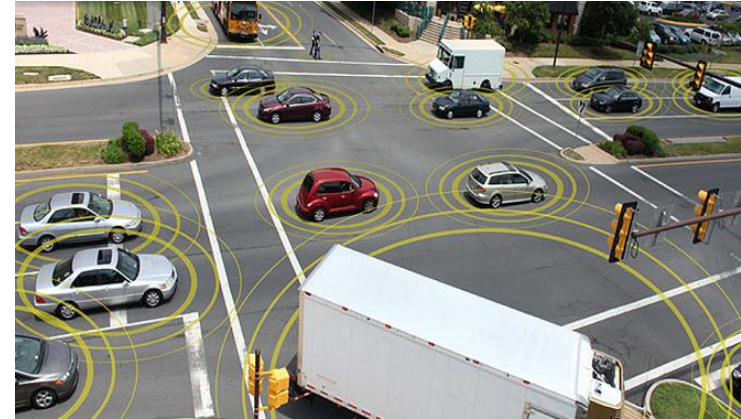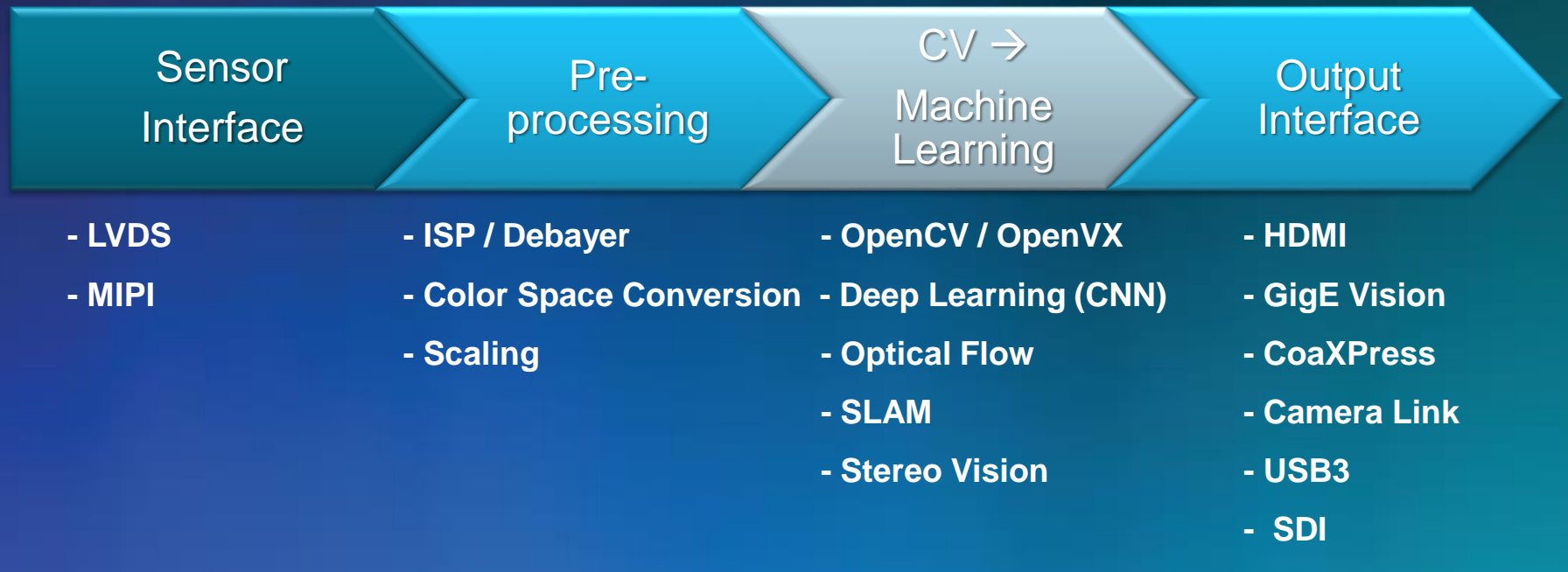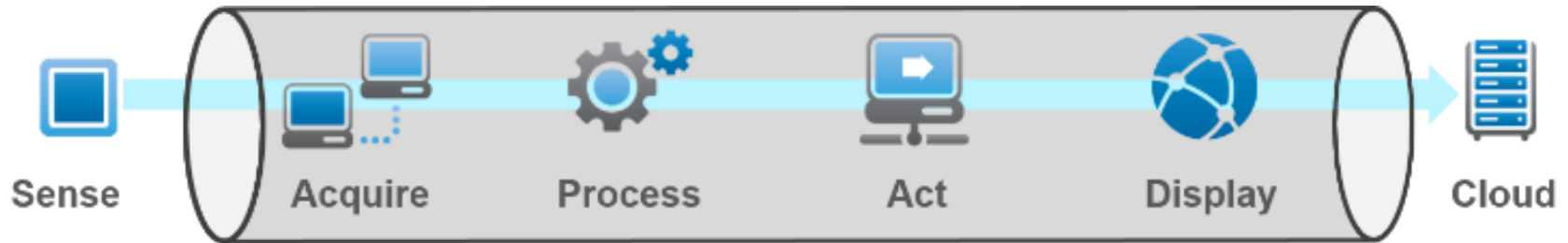**Best Suited for GPGPUs**

Inference

Photo: US DOT

- ❯ Requires efficient processing
- ❯ Does not need the precision of training
- ❯ High volume application targeting…
  - Automotive
  - VGR & Drones
  - Surveillance
  - Medical Imaging
- ❯ Fixed point math used to deploy models

Best Suited for SoCs & FPGAs

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Typical Image Pipeline

Sensor Interface	Pre-processing	CV → Machine Learning	Output Interface

- LVDS
- MIPI

- ISP / Debayer
- Color Space Conversion
- Scaling

- OpenCV / OpenVX
- Deep Learning (CNN)
- Optical Flow
- SLAM
- Stereo Vision

- HDMI
- GigE Vision
- CoaXPress
- Camera Link
- USB3
- SDI

Anatomy of an xReality System

Connectivity
- DVI/HDMI/DisplayPort
- LVDS SERDES
- DDR3/DDR4 x8 or x 16 Memory Interfaces
- MIPI SLVS Interface to LCD Display

Spatial Recognition
- Integrated accelerometer, gyroscope, and magnetometer with *1000+Hz update rate*.
- Eye Tracking to within 1/5th of a degree
- GPS

Video Integration
- Positional tracking via external camera with near-infrared CMOS sensor
- Object Tracking

Power
- USB Powered (<5V budget)
- Battery

Display
- 4K Display
- 100° to 210° field of view
- 60+ FPS
- 120+ Hz refresh rate
- ***Extremely** low latency* to prevent motion sickness

PC/Mobile Integration
- Bluetooth 4.0 LE
- USB 3.0/MicroUSB
- DVI/HDMI/DisplayPort TMDS

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Technical Challenges in VR/AR Systems

➤ **High Performance Required** to Eliminate Simulator Sickness

- High resolution / high bandwidth images for 2560x1920, up to 4K
- High Refresh Rate (120Hz-240Hz)
- Ultra low latency video (<15 ms or lower)

➤ **Field Programmability**: An emerging market, with few standards

- Display Algorithms
- Sensor and Display Integration
- Video analytics
- Eye tracking

➤ **Low Power:** Limited by Battery or Connection

- Tethered systems limited by 5V USB Connectivity

➤ **Time To Market:** Ready-to-Use IP and Libraries shorten TTM

- I2C Interface from stereoscopic cameras
- DVI/HDMI/DisplayPort TMDS Interface
- Interface from inertial sensors
- MIPI CSI2 interface from image sensors
- MIPI DSI interface for Display

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The Xilinx Embedded Vision Ecosystem

Sense → Acquire → Process → Act → Display → Cloud

EMBEDDED SYSTEMS ECOSYSTEM FOR VIDEO / VISION

Sensor Processing	Video Processing	Analytics CV / xNN	Codecs	Connect

DESIGN ENABLEMENT

MODULES & BOARDS

Evaluation Boards
Production Ready SOMS

DESIGN SERVICES

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Xilinx Alliance Program Solutions for AR / VR

logicBRICKS™ — Designed by XYLON

- logiISP (programmable image signal processing IP)
- logiHDR (high dynamic range IP)
- MIPI interfaces (CSI2/DSI)
- Sensor fusion demonstration hardware (logiADAK)

Omnitek

- Full range of IP solutions from sensor input to display output
- Processing blocks including UHD ISP, real-time warp, scalar
- 3D Processing blocks and connectivity IP
- Experts in system integration specializing in efficient low power designs for VR and FPV headsets

XILINX — ALL PROGRAMMABLE™

- Hardware-centric development environment – HLx
- Software-centric development environment – SDSoC
- Xilinx optimized OpenCV libraries
- Video and image sensor IP (HDMI, DisplayPort, MIPI)

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New Embedded Vision Developer Zone

➤ Newly launched developer zone

➤ Supports software, hardware and system-level developers

➤ Rich collection of resources and examples to inspire your next *embedded vision* design

visit: www.xilinx.com/evdz

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Conclusion

➤ The Embedded Vision market is growing fast

➤ Xilinx is the best platform for Embedded Vision for…

  – Any-to-Any Connectivity

  – Sensor Fusion

  – Real-Time Analytics at the Edge

➤ Multi Camera Vision, OpenCV and Machine Learning key trends

➤ Xilinx Makes Embedded Vision Development Easy

  – SDSoC enables rapid development in hardware using C / C++ and vision libraries

  – Predefined hardware platforms to accelerate development

  – Ecosystem of Alliance Program Members with IP, tool flows,

Email: embedded-vision@xilinx.com for this presentation

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Empowering Product Creators to Harness Embedded Vision

The Embedded Vision Alliance (www.Embedded-Vision.com) is a partnership of 50+ leading embedded vision technology and services suppliers

Mission: Inspire and empower product creators to incorporate visual intelligence into their products

The Alliance provides low-cost, high-quality technical educational resources for product developers

Register for updates at www.Embedded-Vision.com

The Alliance enables vision technology providers to grow their businesses through leads, ecosystem partnerships, and insights

For membership, email us: membership@Embedded-Vision.com

Join us at the Embedded Vision Summit
## May 1-3, 2017—Santa Clara, California

The only industry event focused on enabling product creators to create "machines that see"

- *"Awesome! I was very inspired!"*
- *"Fantastic. Learned a lot and met great people."*
- *"Wonderful speakers and informative exhibits!"*

Embedded Vision Summit 2017 highlights:

- **Inspiring keynotes** by leading innovators
- High-quality, practical **technical, business and product talks**
- Exciting **demos** of the latest apps and technologies

Visit **www.EmbeddedVisionSummit.com** **to sign up for updates**
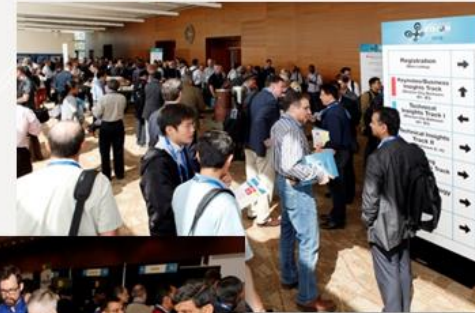
Q & A

For a copy of today's presentation with URLs to learn more about the solution providers presented, email a request to:

embedded-vision@xilinx.com

visit: www.xilinx.com/evdz

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Xilinx Vision with Precision Webinar Series

> Perceiving Environment / Taking Action: AR / VR

> Monitoring Things
- *Machine Vision*
- *Surveillance*
- *Medical Imaging*

| Drones & VGR | ADAS | AR / VR |

Differentiate by Design

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Vision with Precision Webinar Series

AR / VR

Aaron Behman, Xilinx