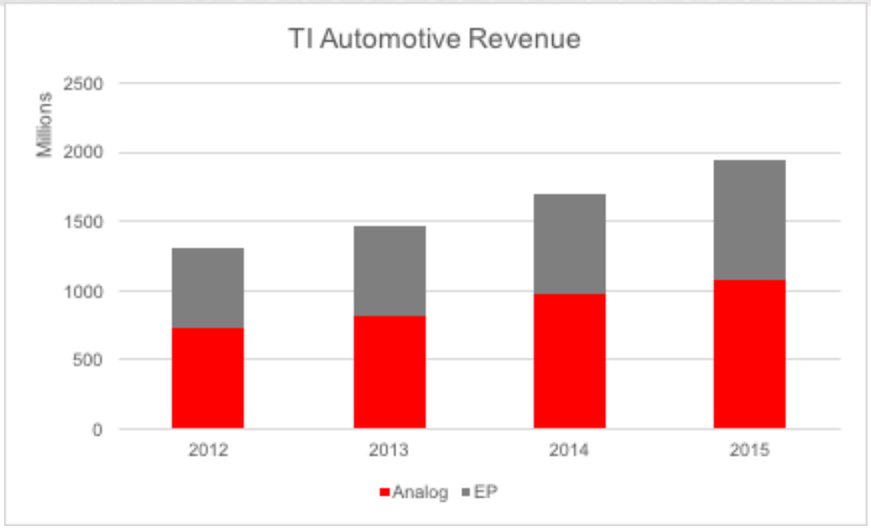
TI Automotive ADAS Processor Solutions

TI Confidential – NDA Restrictions

Oct 2016

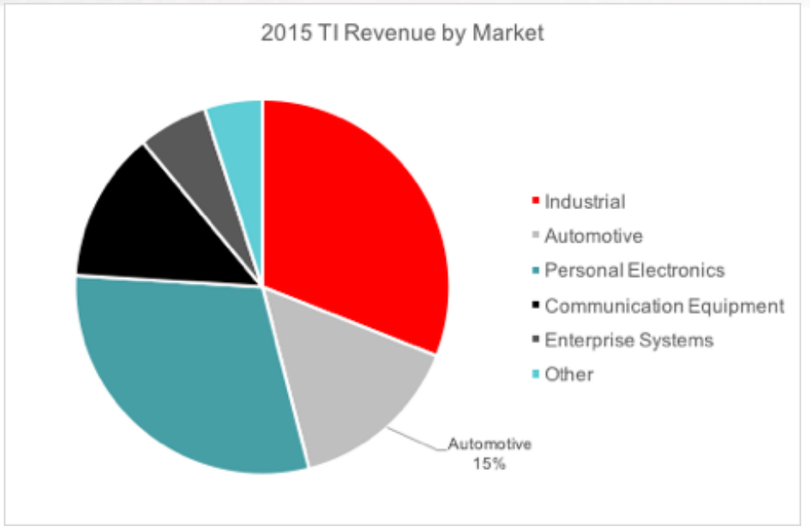
TI IS COMMITTED TO THE AUTOMOTIVE MARKET



15%

OF 2015

TOTAL REVENUE



TI'S AUTOMOTIVE REVENUE IS:

12% OF 2013 → 13% OF 2014 → 15% OF 2015

TOTAL REVENUE

TI R&D INVESTMENTS

22%

ANALOG

EMBEDDED PROCESSING

DLP

>2X

Increase in new products for automotive from 2013 to 2014

TI ADAS SoC's in Active Safety & Autonomous Driving

Over 40 Million TI ADAS SoCs on the road through July 2016

ADAS SoC Business Unit

Tier 1s (> 15)

OEMs (> 25)

Car Lines (> 100)

Common & Scalable HW Architecture

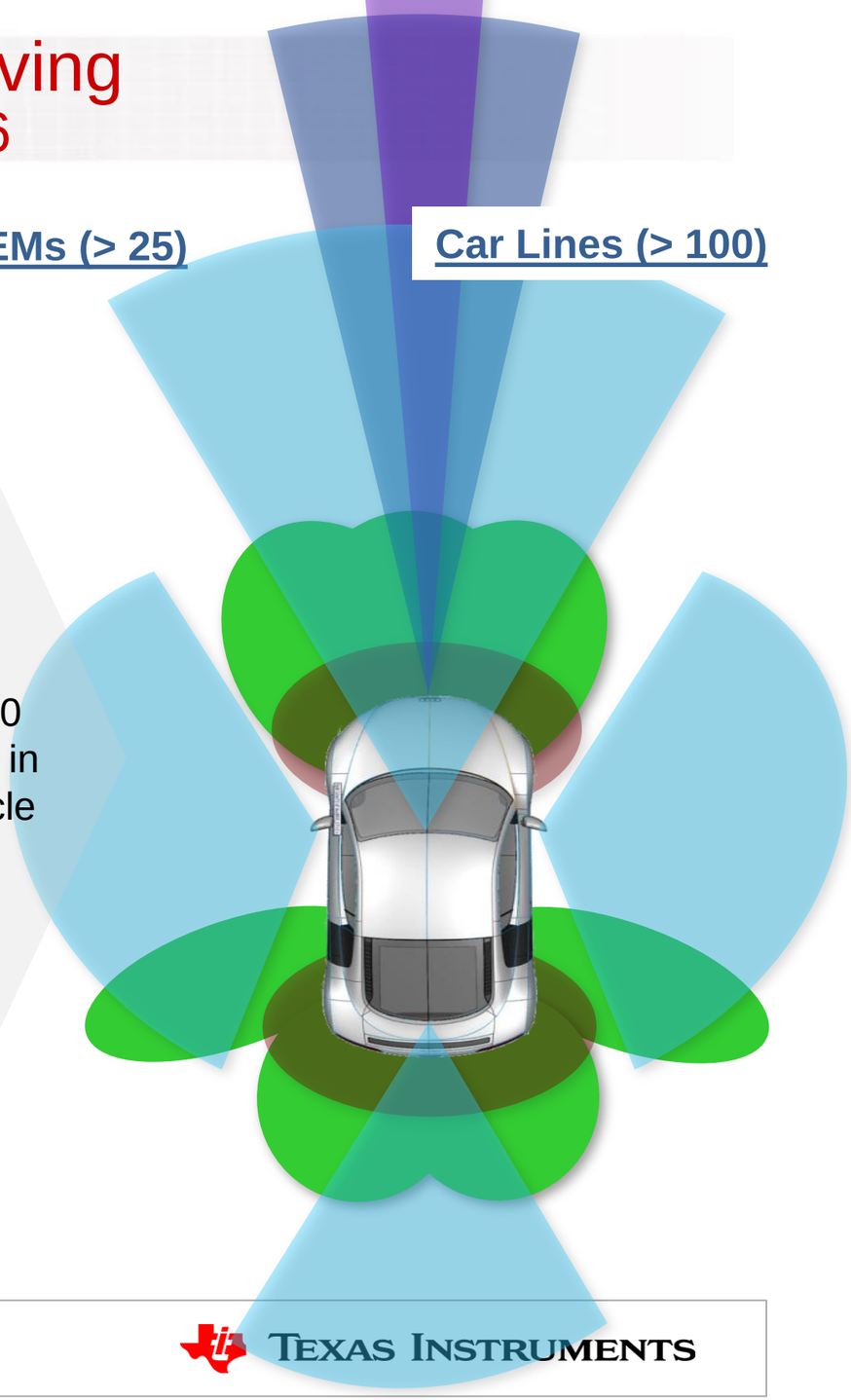
TDAxA ADAS Processor — Front Camera ***A***nalytics

TDAxV ADAS Processor — Intelligent Park Assist ***V***iewing

TDAxR ADAS Processor — Intelligent ***R***adar

TDAxF ADAS Processor — ADAS ***F***usion

Up to 10 TI SoCs in on vehicle



Software

Vision SDK Kernel Libraries → **Innovative ADAS Algorithms**

Target ADAS Applications

Core Applications

Front Camera

Scalable Performance
Low Power
Safety

Surround View

Integrate 3D Graphics
Scalable Analytics
Security

Rear Camera

Low Power
Small Footprint
Scalable Analytics

Radar

Scalable performance
MCU Integration
Safety

Emerging Applications

Sensor Fusion

High Performance
Safety
Security

Driver Monitoring

Small Footprint
ISP Integration Scalable Analytics

Mirror Replacement

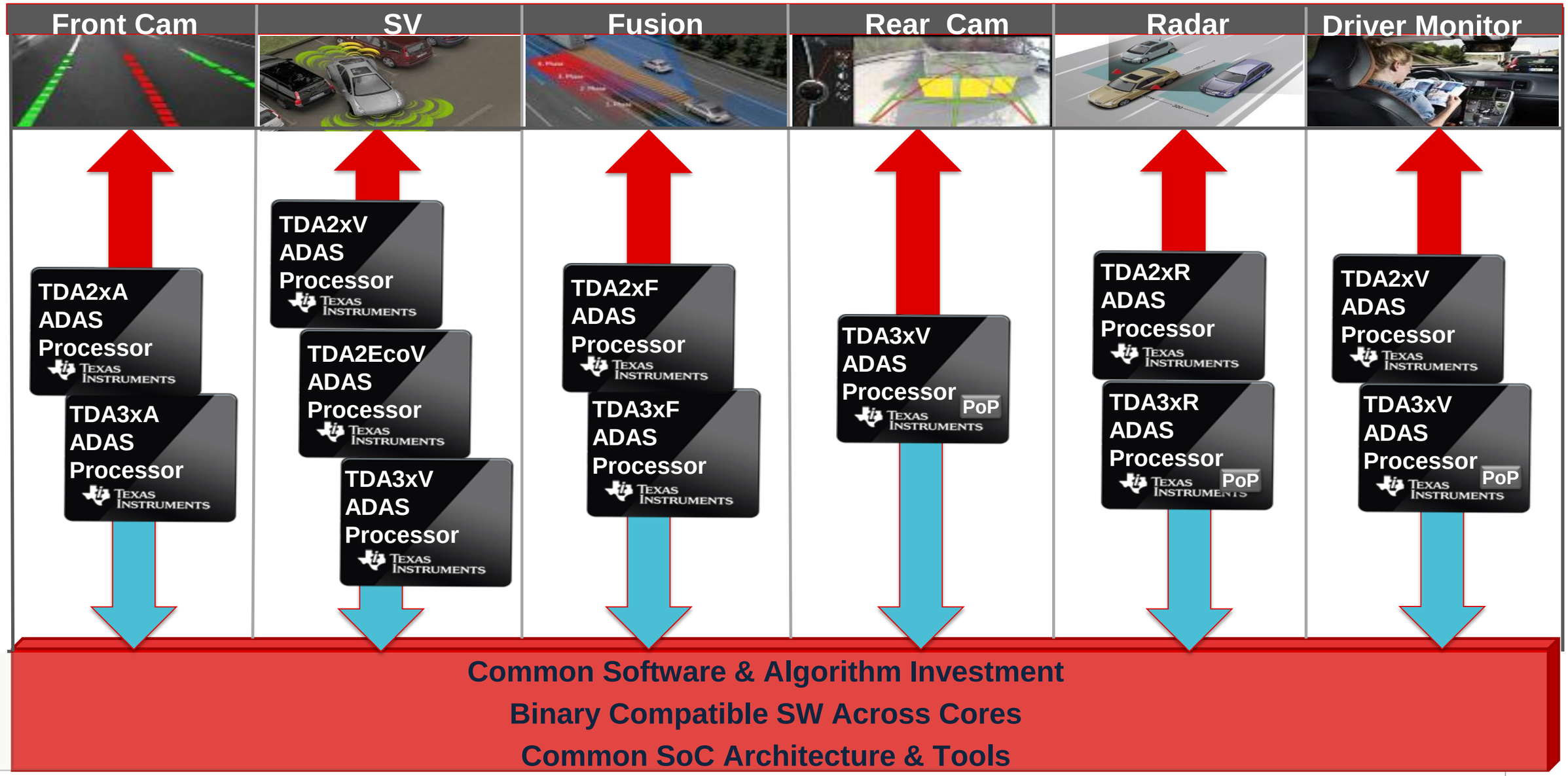
Performance
ISP Integration
Scalable Analytics

Lidar

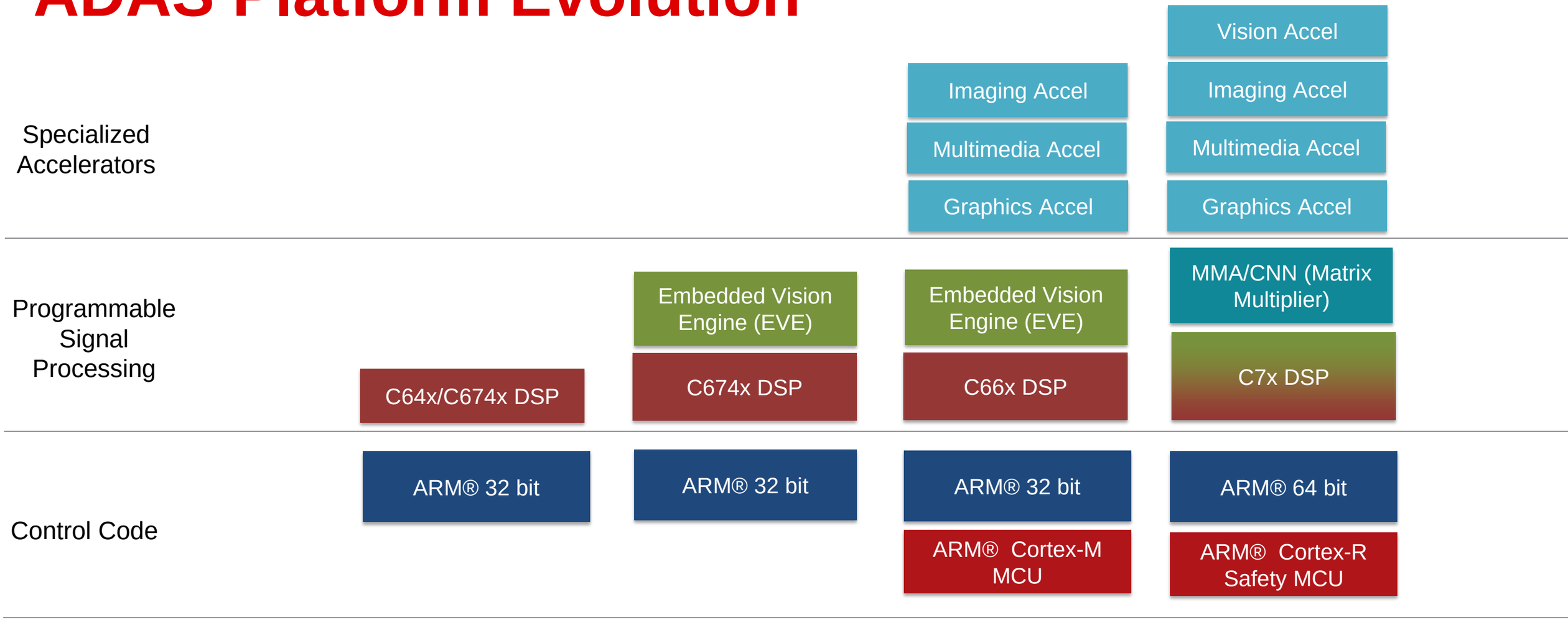
Scalable Performance

Scalable premium to entry performance solutions.
Fully programmable DSP, Vision Accelerators, and ARM cores.
Software Development Kits and Libraries provide easy portability between platforms.

Current Gen TDA Family Scalability

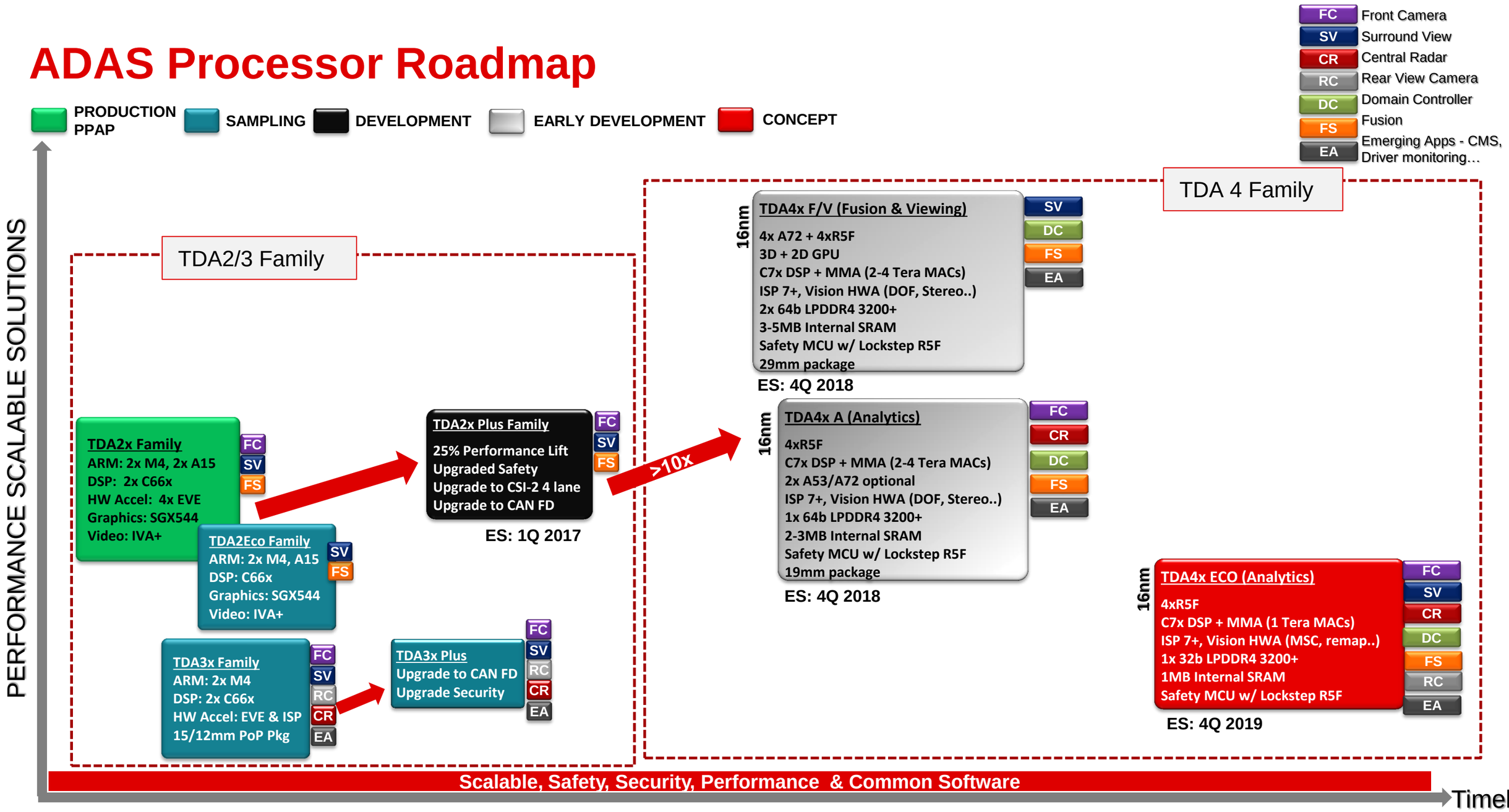


ADAS Platform Evolution

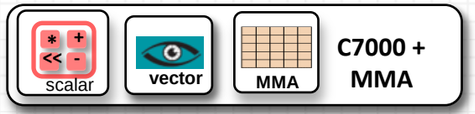
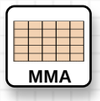


Generation	Gen 0/1	Gen 2	Gen 3	Gen 4
ASIL Enablement	A	B	B	C
Part Family	C67x/OMAPx/DMx	TDA1x	TDA2/3x	TDA4x

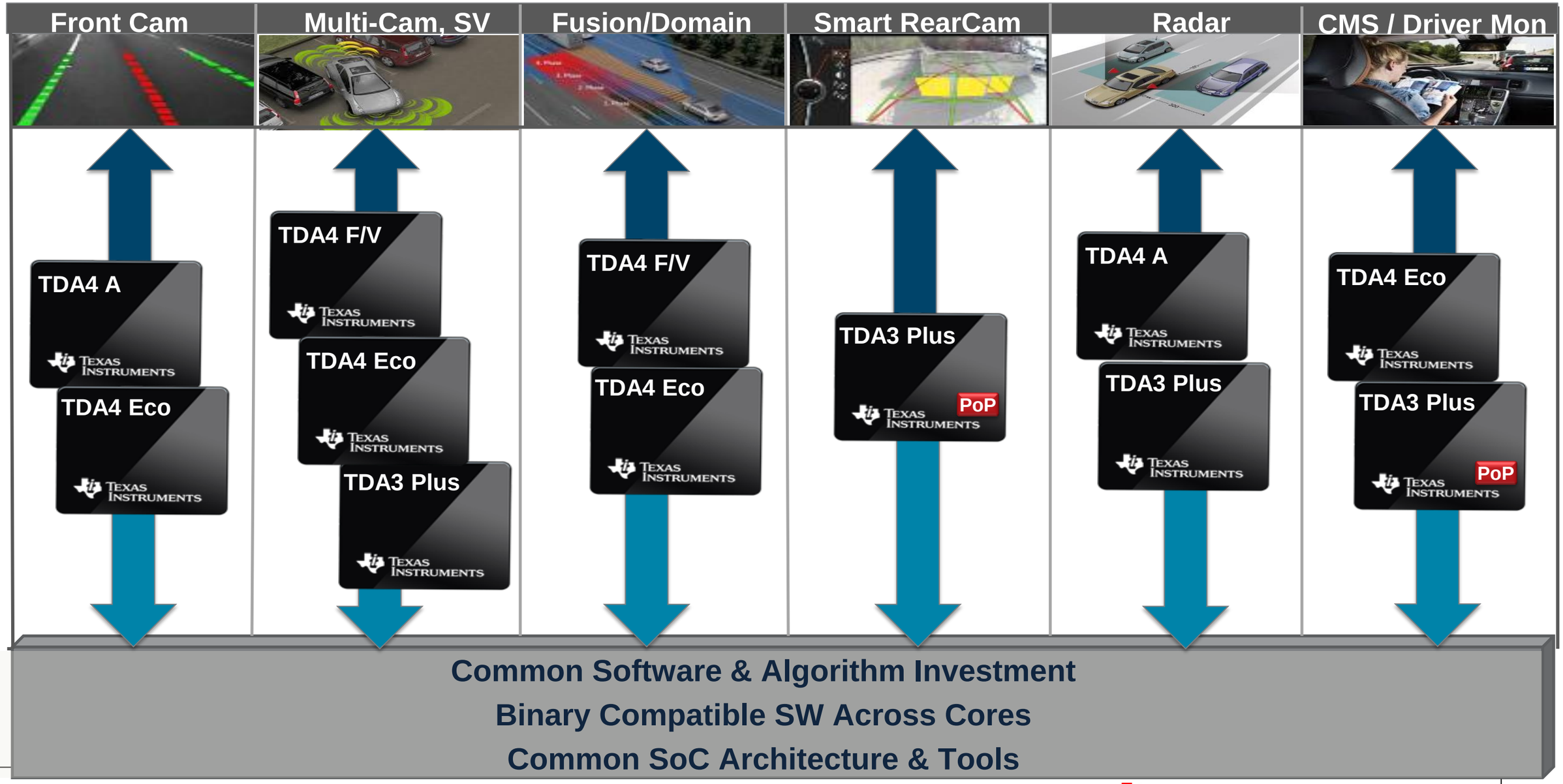
ADAS Processor Roadmap



TDA4 Platform Snapshot

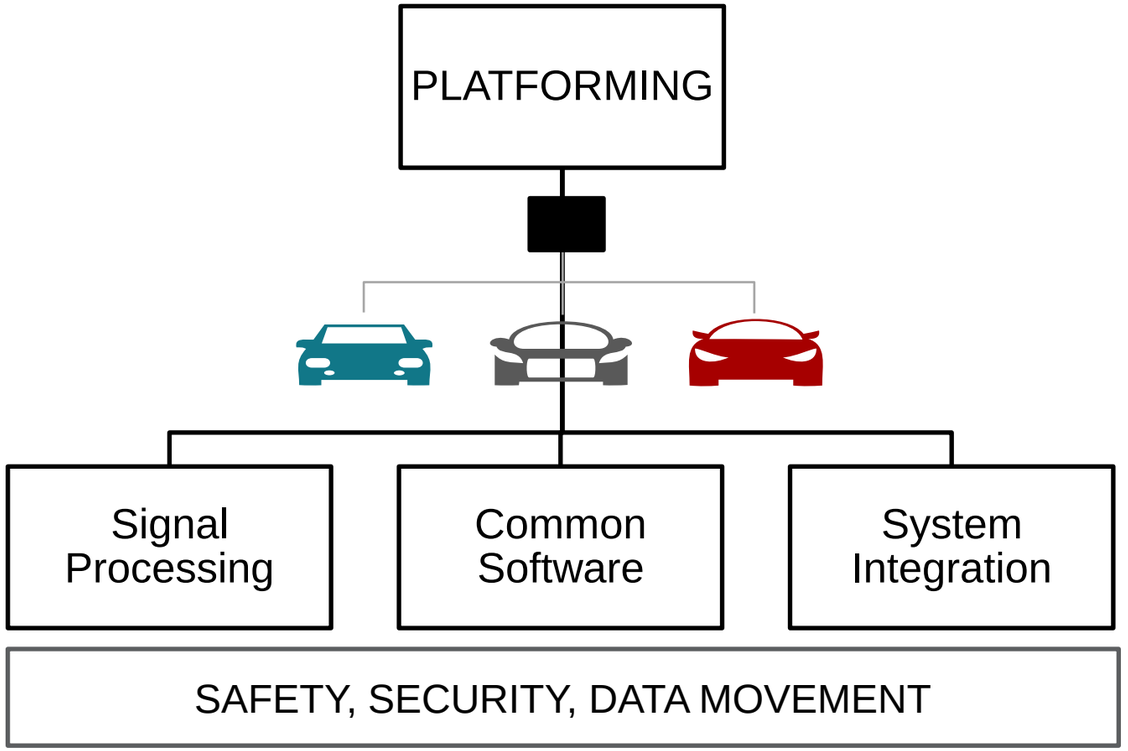
CLUSTER	FEATURES			ENABLING
ARM CPU	 50K DMIPs	 4x Aux Cores	 Lockstep SafeTI™ MCU	• High performance Fusion DMIPS • Integrated Safe MCU
DSPs / Graphics	 C66x+EVE -> C7000 DSP	 4096 MAC/cycle	 250 GFlops	• Simplified SW Dev. • >4 TeraMACs deep learning accelerator
Vision & Multimedia	 ISP 7.x, Vision HWA	 Multiple 2-4K display	 Encode + Decode	• >10 2MP cameras at lowest BOM • Optimized Acceleration
High Speed IO	 >50 Gbytes/s	 PCIe 3, USB3.1, >10G Serdes	 10G Enet Switch	• Performance • System Flexibility • Switch integration
Security & Security	 Enhanced Firewall	 Central Security & PWR	 Cryptos, security HWA	• V2V, V2X Security Ready • Enhanced platform safety and FFI
Software				• AutoSAR ready • ISO26262 development compliant

Next Gen Scalable TDA Family



Our strategy is to differentiate through…

- **Common & Scalable Platform**
  - Common Platform scaling from Entry, Mid to High
  - Scalable compute using HyperLink™
- **Common Software**
  - Vision SDK baseline
  - Dedicated Housekeeping MCU
  - Dedicated Safety MCU w/ AUTOSAR
- **Efficient Vision Compute**
  - Right tradeoff of programmable vs. fixed acceleration
  - Best power efficiency
- **Efficient Data Movement Architecture**
  - Cache, Data & IO Coherency
  - Data compression
  - Streaming based architecture
  - High bandwidth links with ultra low latency
- **Safety & Security**
  - Dedicated Safety MCU
  - Dedicated Security & Device Management Processor
  - Dedicated Security Accelerators
- **High System Integration**
  - On die. Extensive Analog Integration
  - Next Gen PM Solutions
  - Next Gen. Interfaces for Interprocessor communication & Chip to Chip connectivity



TI Vision

Gen 2 – ADAS

- DSP - C66x
- Vision -EVE
- **ISP – Imaging HWA**

- **More cores**
- C66x
- EVE

- **C66x - DSP**
- **EVE – Vision coprocessor**

Gen 3 – Highly Autonomous Driving

- C7x – New powerful DSP with Vector Core
- ISP – Vision Optimized ISP
- DOF, Stereo
- MMA – Powerful programmable Matrix Co-processor optimized for CNN & other matrix operations
- High Security

Gen 4 – Fully Autonomous Driving

- C7x plus – Same architecture plus
- ISP plus – enhancements & speed increase
- Vision HWA plus – enhancements
  - DOF
  - Stereo
  - **Other**
- MMA – Enhancements for more powerful CNN & Matrix operation processing
- **Communication**
- **Bandwidth reductions & improvements**

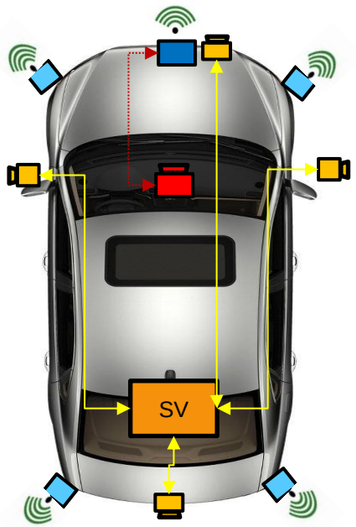
16nm FF provides 5-6X performance boost at same power

ADAS — ***ADAS to Autonomous transition*** — **Autonomous Driving**

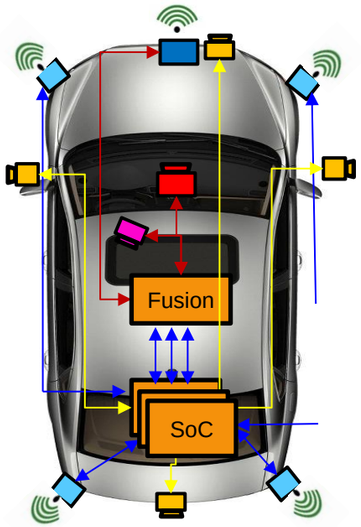
ADAS System Migrations

Parking Camera
Front Camera
Interior Camera
LR Radar
MultiMode Radar

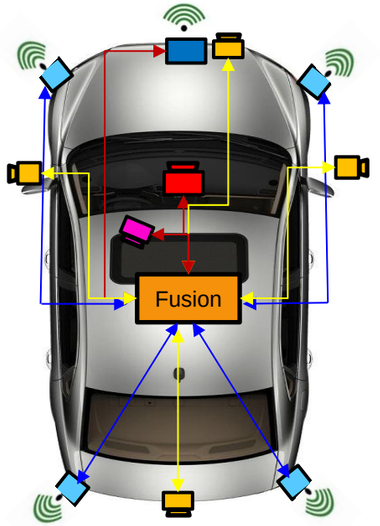
Distributed



Hybrid



Fully Centralized



Distributed Systems

- State of the art today
- Processing on the edge – processor close to sensor
- Easy to manage - Clear ownership
- Power and size constraints

Hybrid "Centralized" System

- Hi speed transmission of RAW data to dedicated centralized processor node
- Aggregate common sensor nodes into Central Fusion ECU - Each processor node transmits object data to fusion ECU
- Easy to manage - Clear ownership
- Easily Scalable
- Sensing Units can be very small
- Processing Units Power & Size can be relaxed

Full Centralized Processing

- Very complex, expensive, and difficult to scale to lower cost vehicles (zFAS)
- Difficult to manage multi-vendor Collaboration on one chip
- Multiple vendor systems on one chip raises safety and responsibility issues

TI has extensive knowledge and market presence in each of these building blocks on a common HW & SW platform, allowing easy migration between system architectures.

Ecosystem - ADAS

Texas Instruments Design Network

TDA's Engineering Consultancy Partners

KPIT · D3 Engineering (Define | Design | Deploy) · FotoNation (a TESSERA company) · ITK-Engineering · automotive engineering iav · SCS super computing systems · PATHPARTNER

TDAx SoC

Graphics

2D | 3D

Texas Instruments · Imagination · D3 Engineering (Define | Design | Deploy)

ARM® Cortex®-A15

Graphics / HMI | Middleware | OS services

QNX · LINUX · mentor embedded · Green Hills SOFTWARE · TRUSTONIC · Texas Instruments

Auxiliary ARM® Cortex®-M4

RTOS

Texas Instruments · Green Hills SOFTWARE · mentor embedded

Automotive Stack (eAVB, CAN, MOST, AUTOSAR etc.)

Elektrobit · vector · mentor embedded

C66x DSP/EVE

Algorithms

KPIT · Hella Aglaia · Dream CHIP · PATHPARTNER · D3 Engineering (Define | Design | Deploy) · FotoNation (a TESSERA company)

Optimizations

D3 Engineering (Define | Design | Deploy) · PATHPARTNER · ITK-Engineering · TATA CONSULTANCY SERVICES · SCS super computing systems · KPIT · automotive engineering iav

RTOS

Texas Instruments · mentor embedded

ISP

Sensor/Image Tuning

MMS · D3 Engineering (Define | Design | Deploy)

CODECs

Texas Instruments · PATHPARTNER · Ittiam

TDA Hardware Board Design

Spectrum Digital Incorporated · VVDN Technologies · D3 Engineering (Define | Design | Deploy) · RT-RK

D3 Engineering – RVP

TDAx Rugged Vision Platform

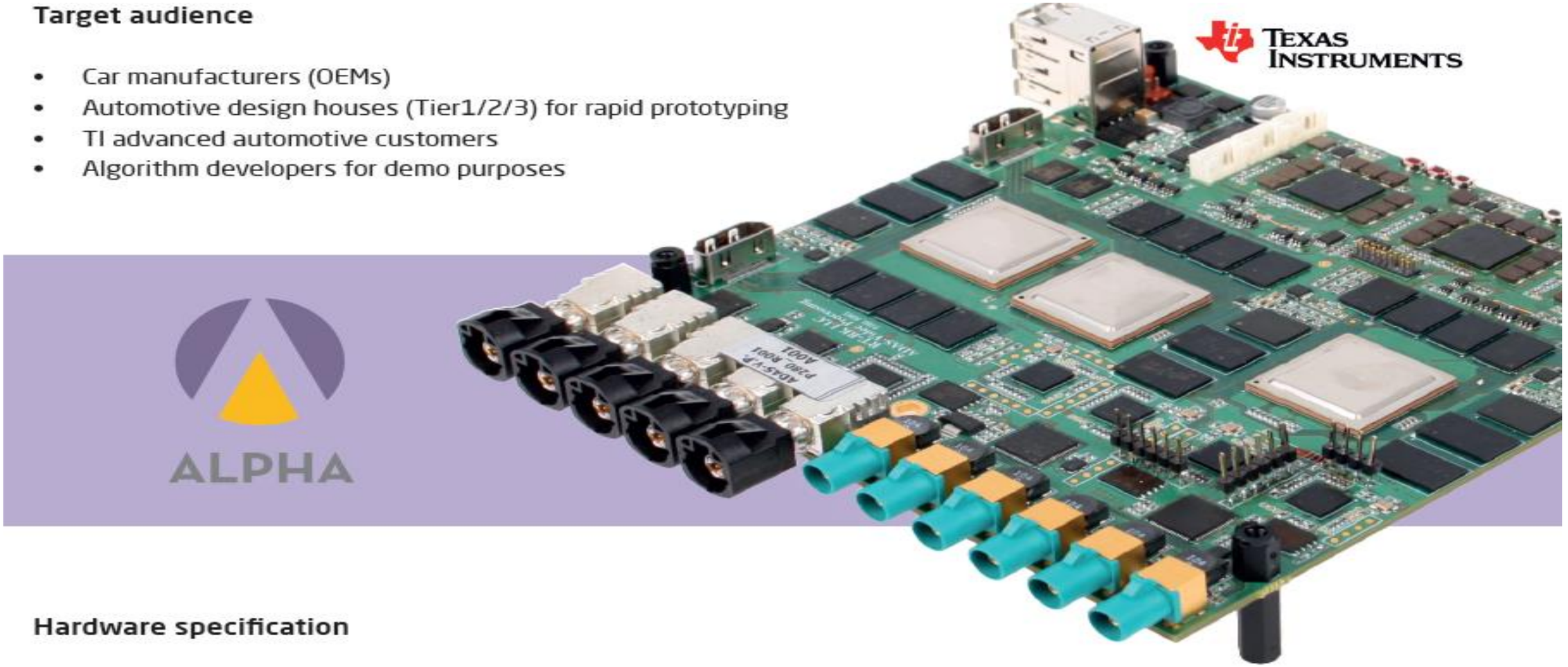
- ✓Small form factor
- ✓Ready for on-vehicle testing and prototypes
- ✓Automotive ready
- ✓Production support from D3
- ✓ISP tuning and algorithm optimization from D3
- ✓Multiple sensors supported

A fully functioning evaluation system speeds on-vehicle testing and development of multi-camera, real-time vision applications requiring intensive video analytics.

RTRK Automotive Machine Vision (AMV)

Target audience

- Car manufacturers (OEMs)
- Automotive design houses (Tier1/2/3) for rapid prototyping
- TI advanced automotive customers
- Algorithm developers for demo purposes



Hardware specification

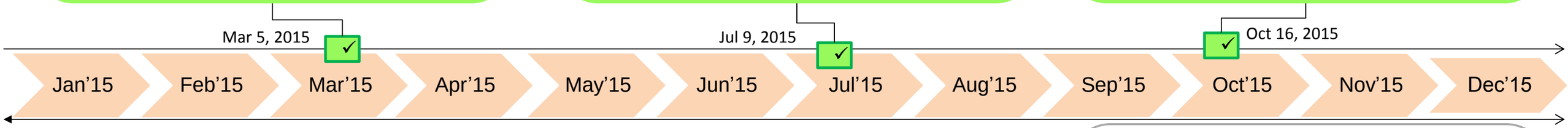
- Processors: 3 x TDA2x SoC (up to 2x ARM Cortex A15 and 2x ARM Cortex M4, 2x C66x Digital Signal Processor cores (DSP), 4x Embedded vision Engine (EVE)).

TDA2x/2Ex/3x – Processor SDK – Vision (Vision SDK) 2016 ROADMAP

v2.06
- Power Management
- ISS Image tuning tool (TDA3x)
- 4-Ch 2D Surround View Demo (TDA3x)
- AWB, AE library (TDA3x)
- Tuned AR140, OV10640 with WDR (TDA3x)
- Linux Kernel v3.14, GLSDK 7.0

V2.07
- Boot optimization (TDA3x)
- TeSoc, ECC, CRC, WWDT (TDA3x)
- 4-ch low cost surround view with TI960H on TDA2x/2Ex, internal ISP on TDA3x
- Removal of Dynamic memory allocation from links/drivers
- SBL/StarterWare MISRA-C compliance

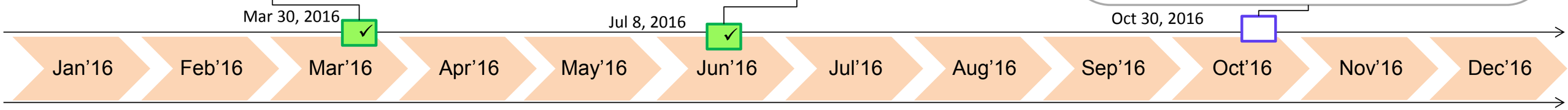
V2.08
- Quality Managed (non safety) Production Ready
- EVE library, ISS Drivers and Vision-SDK Links MISRA-C compliance
- Linux Kernel v3.14, GLSDK 7.01
- Improved 3D Surround View SGX Demo



2.09
- ECC, RTI, DCC, ESM, FFI for DSP, EVE
- Diagnostic Library (SPI, ECC, ADC, CRC)
- Improved Object detect, Traffic Light recognition, Structure from Motion
- NCC on EVE Lib, CNN kernels on DSP VLIB
- Linux Kernel v3.14, GLSDK 7.03
- SGX Off screen rendering

2.10
- Secure boot on TDA2x/2Ex
- High throughput Ethernet
- TDA3x 3D SRV, 4 Ch 2A, 2D+3D, ~7s boot
- OpenCV/CL (A15)
- Linux Kernel v3.14, GLSDK 7.04

2.11
- TDA3x: Secure boot, MCAL: CAN-FD Alpha
- 3P (MMS, D3) 2A eval algorithms, 2MP Sensor
- TDA3x 3D SRV, WDR, ~2s boot,
- CSI2 capture driver on TDA2E
- Full 360 view generation tool for TDA3x SRV
- OpenCV, OpenCL, OpenVX , DSP acceleration
- Linux kernel 4.4, Processor Linux SDK 3.0
- Radar SDK (cut down for Radar only solutions)



OpenCL, OpenVX and OpenCV

	OpenCL	OpenVX	OpenCV
Computer vision Library	NO	Yes	Yes
Defines a programming language	Yes	NO	NO
Defines an acceleration framework	Yes (Language based)	Yes (Graph based)	NO
Open standard API defined by Khronos	Yes	Yes	No (community driven open source)
Library Scope	NA	~43 vision kernels (v1.1) with user extension capability	~2500 vision and machine learning functions

OpenXX Availability from TI

	OpenCL	OpenVX	OpenCV
Availability	Yes	VXLIB: Yes OpenVX API: TBD	Yes
Devices	*TDA2x, AM57xx, DRA7xx & K2X*	*TDA2x, TDA3x, AM57xx, DRA7xx & K2X*	*TDA2x, AM57xx, DRA7xx & K2X*
Comments	DSP exposed as generic OpenCL compute device EVE will be exposed as custom device	OpenVX Kernels will be available on DSP (VXLIB) OpenVX API: Under implementation	Avaialbity of modules on A15 and acceleration to EVE/DSP

Timelines	DSP (compute device) : 3Q-2016
	
	EVE (custom device) : 1Q-2017
		OpenVX Kernels on DSP (VXLIB):
		3Q-2016 (Beta)
		4Q-2016 (GA)
			• A15
			  • Available
			• DSP Acceleration
			  • 4Q-2016(Beta)
			• EVE Acceleration
			  • 1Q-2017(Beta)