DRIVE Platform For Developers

February 2023

Agenda

Link to Latest Online PDF Version

- DRIVE Platform Overview
- DRIVE SDK
- DRIVE Sensor Support

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DRIVE Platform Overview

DRIVE Hyperion 8.1 DevKit

Functionally safe production ready AV + IX platform

- Open, scalable production-ready platform*
- 3 Orin computer architecture:
  - Dual DRIVE Orin SoCs for DRIVE Chauffeur (AV)
  - Single DRIVE Orin SoC for DRIVE Concierge (IX)
  - Form factor & API compatible for Thor upgrade
- Qualified sensor suite that encompasses 12 cameras, 9 radars, 1 lidar, 12 ultrasonics, subset configurations possible
- High quality 4D data collection ready
- Designed for the highest level of functional safety and cyber security
- Scheduled for 2024 production vehicles globally

** Contact NVIDIA representative for more details*

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DRIVE AGX Orin DevKit

Open & scalable platform purpose built for automotive

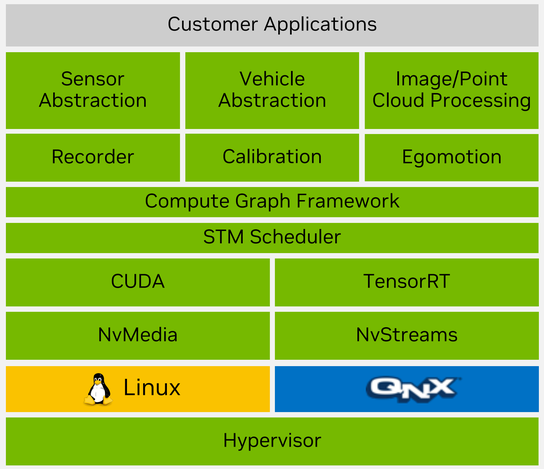
Sensor Diversity

- Diverse, ISO 26262 compliant sensors
- Large ecosystem of automotive partners
- End to end sensor life cycle management

Camera | Radar | Lidar | Ultrasonic | GPS | IMU

Drive SDK

- Includes DRIVE OS and DriveWorks
- Rich suite of automotive developer tools
- Compute graph framework enables execution of complex pipelines
- Deterministic runtime scheduler orchestrates execution of graphs across hardware engines
- ISO 26262 safety certifiable DRIVE OS QNX, drivers, and platform APIs
- Resource isolation & QoS



Drive AGX Orin

- Powered by single Orin SoC delivering up to 254 TOPS
- Includes hardware, software and sample applications needed for development of production level autonomous vehicle applications
- Built on production auto-grade silicon
- Provides rich automotive I/O and flexibility to expand
- Base kit for bench development and add-on vehicle kit for vehicle installation

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DRIVE AGX Orin DevKit (cont.)

Complete self-driving hardware and software development kit

- Single Orin SoC delivering up to 254 TOPS
- Modular design, shared with Jetson (Embedded), Isaac (Robotics) & Clara (Healthcare) AGX
- Rich automotive I/O with flexibility to expand
- Base kit for bench development and add-on vehicle kit for vehicle installation
  - Smaller footprint
  - Integrated power supply
  - Improved unboxing, system & accessories in single box
  - Unified DRIVE SDK release includes DRIVE OS & DriveWorks
  - Docker support
  - Debian packages
- Commercially available platform
  - $7K NVIDIA list price for base developer kit
  - $875 NVIDIA list price for add-on vehicle accessory kit
  - Available directly from NVIDIA and authorized distributor
  - No signed agreements required

Available Now!

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DRIVE AGX Orin DevKit (cont.)

Complete self-driving hardware and software development kit

DRIVE AGX Developer Kit			
	Scalable AV Platform with DRIVE Orin Module	**I/O**	**Supports DRIVE SDK**
DRIVE AGX Orin DevKit 37cm*15cm*15cm 	• Up to 254 TOPS (CUDA Tensor Core GPU + DLA) • 12 Arm Cortex-A78AE CPUs • Architected for safety • Connect up to 4 computers using multi-lane interconnect • $7K NVIDIA list price	• 16x GMSL cameras (through 4x Quad-GMSL) • 2x 10 GbE, 10x 1 GbE & 6x 100 MbE • DisplayPort 1.4	• DRIVE OS with DriveWorks, NvMedia, NvStreams, CUDA, cuDNN, TensorRT • Rich suite of developer tools

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

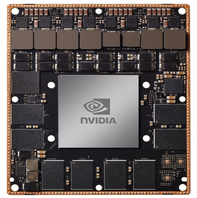
DRIVE Hardware Offering

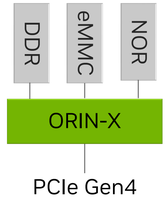
Modularity | Flexibility | Configurability

DRIVE Modules (For Production)

DRIVE Orin Module

Offloads Sensor Data Processing

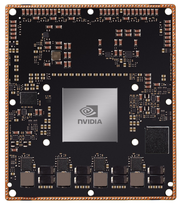


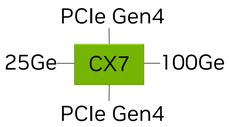


Camera	SoC Capability	
• 16 CSI at 164 Gbps pixel input • 1.8 Gpixel/s ISP processing • USB, PCIE Gen4, 10 GbE, 1 GbE, HDMI/DP (MST), CAN and serial I/Os	• DL Inference 254 INT8 TOPS • CPU 228 KDMIPs • > 5000 FP32 CUDA GFLOPs • 256b LP5 DDR 32 GB at 205 GB/s • eMMC 64 GB	• 135W (depends on workload)

DRIVE ConnectX-7 Network Processing Module

Automotive Centric Network Adapter

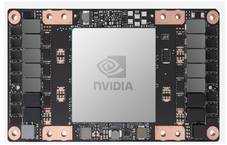


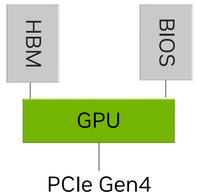


I/O	Security	Offloads	Networking
• PCIE Gen4, multi-host, host chaining, 100GbE, 25GbE, 4 MACs	• 16x GMSL cameras (through 4x Quad-GMSL)	• TCP/IP, UDP, zero copy, real time protocol	• RDMA, time-sensitive networking

DRIVE PG199 GPU Module

Peta OP Capable, Partitionable PG199 GPU





Performance	Memory Capacity	Available MIG partitions	SXM2 form factor
• > 900 TOPS	• 32 GB • > 1400 GB/s	• 6 partitions	• PCIE Gen 4 • Up to 375W

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Benefits of Upgrading To DRIVE AGX Orin

	DRIVE AGX Xavier DevKit	DRIVE AGX Orin DevKit
SoC	Xavier (x2)	Orin (x1)
DL Inference TOPS (INT8)	60 TOPS	254 TOPS
Memory Bandwidth	Per Xavier – 136 GB/s	Per Orin – 205 GB/s
System RAM	32GB LPDDR4 (2133 MHz)	32GB LPDDR5 (3200 MHz)
Networking	100 MbE (x5) 1 GbE (x7) 10 GbE (x2)	100 MbE (x6) 1 GbE (x10) 10 GbE (x2)
Wireless Connection	No	Wi-Fi / Bluetooth
Operating System	DRIVE OS 5 Linux | QNX for Safety	DRIVE OS 6 Linux with Safety Extensions | QNX for Safety
Middleware Framework	DriveWorks 3 & 4	DriveWorks 5 (Compute graph framework)
Deterministic Scheduler	No	System Task Manager
Developer Tools	CUDA 10.2 TensorRT 6.4 cuDNN 7.6	CUDA 11.x TensorRT 8.x cuDNN 8.x

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DRIVE AGX Orin For Automotive

	Jetson AGX Orin DevKit	DRIVE AGX Orin DevKit
Segment	Embedded & Robotics	Automotive
Power	60W (MAXN mode, module power)*	100W (Module power)
Input Voltage Range	7V to 20V (High), 5V (Mid)	9V to 16V (Static), 7V to 32V (Transient)
DL Inference TOPS (INT8)	275 TOPS**	254 TOPS
Operating Temperature	0 to 35C	0 to 45C
Safety MCU	No	Infineon Aurix TC397
Networking	1 GbE RJ45 10 GbE RJ45 M.2 Key E (WLAN / BT, PCIe, USB 2.0, UART, I2S & I2C)	1 GbE RJ45 10 GbE RJ45 100 T1, 1000 T1, 10 GbE T1 CAN, LIN, Flexray, USS DisplayPort 1.4 18x networking ports (High reliability auto grade)
Storage (Default stuffing)	64GB eMMC 5.1 MicroSD M.2 Key M (NVMe)	1x UFS (256 GB)
Video	MIPI CSI-2	16x GMSL-In (Auto grade, GMSL1 & GMSL2, support up to 16 cameras)

** Need to choose required compute engines to run application and stay within power budget*
*** Bumped performance up on Orin SoC (not auto grade) GPU & DLA*

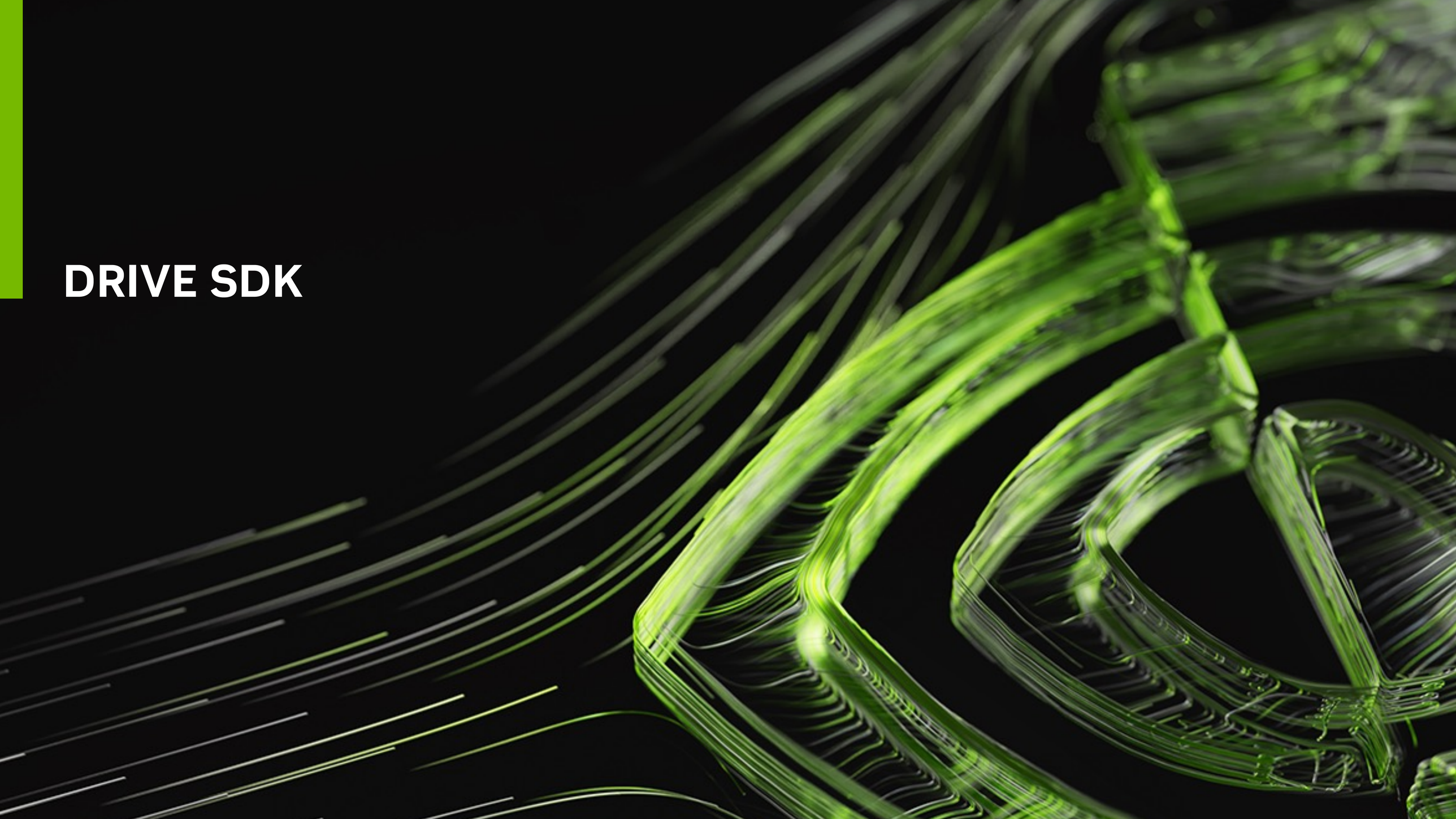
NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DRIVE AGX Orin For Automotive (cont.)

	Jetson AGX Orin DevKit	DRIVE AGX Orin DevKit
Operating System	Linux4Tegra (Ubuntu) Secureboot, trusted execution environment, disk and dram encryption, crypto acceleration, hardware-based security fuses	DRIVE OS Linux with Safety Extensions | QNX for Safety Comprehensive safety & security services: Functional safety island integration, streamlined safety framework, platform security controller integration, secure boot & PKCS #11 support for crypto acceleration features
Bootloader	UEFI	Quickboot: Optimized for real-time applications
Computer Vision	VPI (Image processing algorithms supported on multiple compute engines like CPU, GPU, PVA, VIC)	NvMedia: Highly optimized APIs to access multiple compute engines and sensors
Multimedia	MM API / V4L2 API / Gstreamer	NvMedia: Up to 16 cameras for simultaneous processing with hardware acceleration
Imaging	Librargus (Multimedia, ISP access)	NvMedia SIPL: Provides proprietary optimized ISP algorithms for production
SDK	Compute / Inferencing: CUDA, cuDNN, TensorRT Inference serving: Triton inference server Cloud native: Nvidia container runtime Tools: Nsight Systems (Performance analysis), Nsight Graphics (Debug, profiler and export with Direct3D), Nsight Eclipse Edition (IDE), Nsight Compute (Interactive kernel profiler for CUDA applications)	DriveWorks: Sensor abstraction (camera, radar, lidar, ultrasonic, CAN, GNSS/ IMU), vehicle abstraction, image/point cloud processing, compute graph framework, DNN framework, recorder, calibration, egomotion NvMedia, NvStreams, CUDA, cuDNN, TensorRT, Triton inference server, NVIDIA container runtime Tools: Nsight Systems (Performance analysis), Nsight Graphics (Debug, profiler and export with Direct3D), Nsight Eclipse Edition (IDE), Nsight Compute (Interactive kernel profiler for CUDA applications)

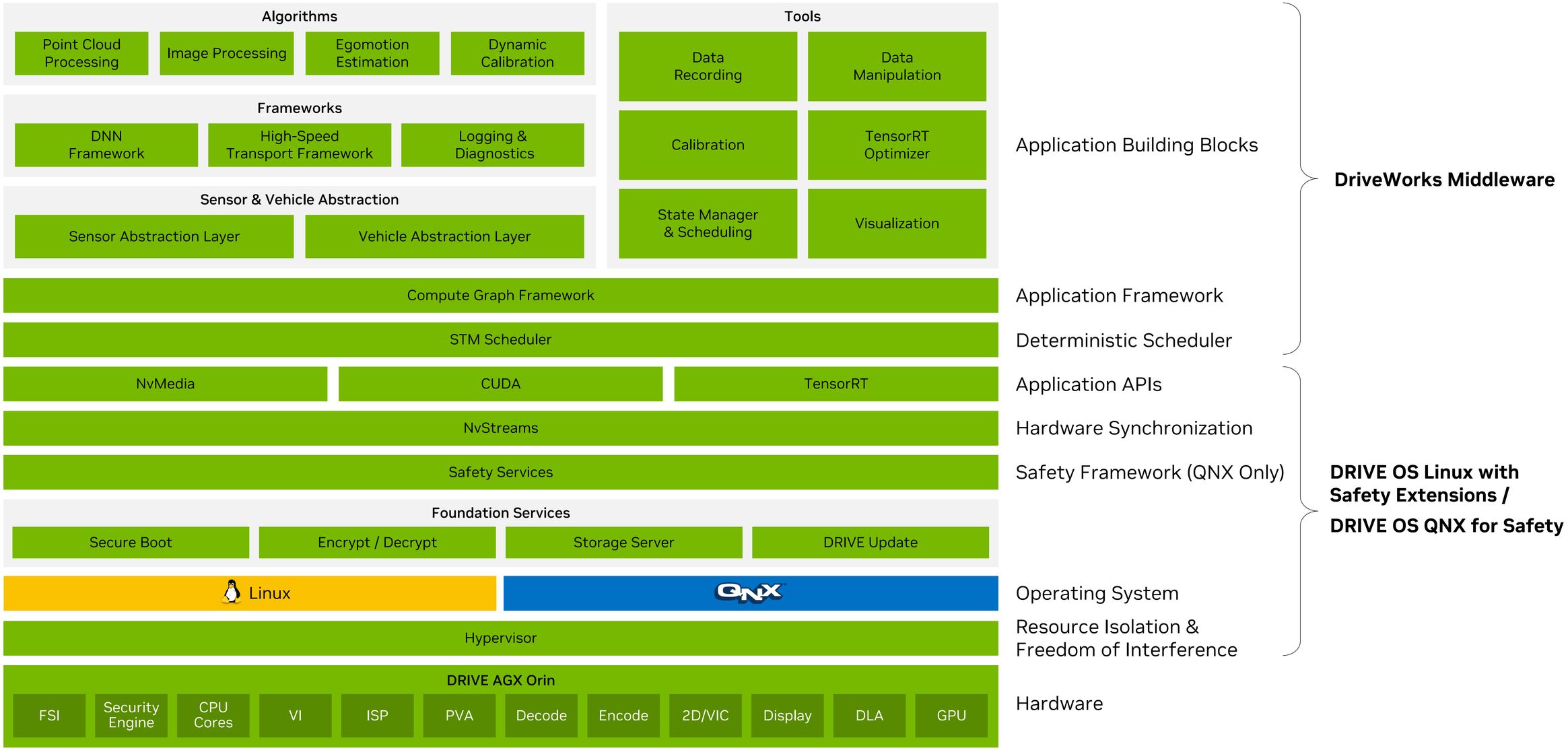
NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DRIVE SDK



DRIVE SDK Supercharge AV Development

One architecture | DRIVE OS & DriveWorks | DRIVE AGX Orin



NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Accelerate Development With DRIVE SDK

Rich suite of developer tools & frameworks

Tool	Function
Nsight Systems	Visualize application algorithms, select the largest opportunities for optimization, and tune to scale efficiently across CPUs and GPUs on the DRIVE platform
Nsight Graphics	Standalone developer tool that lets you debug, profile, and export frames built with Direct3D (11, 12, DXR), Vulkan (1.1, NV Vulkan Ray Tracing Extension), OpenGL, OpenVR, and the Oculus SDK
Nsight Visual Studio Code Edition	IDE to develop CUDA applications and create a homogeneous development environment for heterogeneous platforms
Nsight Compute	Interactive kernel profiler for CUDA applications that provides detailed performance metrics and API debugging via a user interface and command line tool
Sensor Abstraction Tools	Displays connected sensor devices & configurations, initializes all sensors, performs sanity check
Sensor Recorder and Replay	Records sensor data with time sync, verifies sensor integrity, replays sensor data and visualizes configuration, converts LRAW input files into output files, exports video streams in MP4 container
Sensor Calibration	Camera and IMU calibration tools
DNN Framework	Optimizes Caffe, UFF, ONNX models using TensorRT
Compute Graph Framework	Software infrastructure that allows for the construction of a peer-to-peer network of processes, which implements complex execution pipelines such as self-driving applications
Deterministic Scheduler	Schedule Task Manager tools to see compute graphs on all applications to improve application scheduling

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DRIVE SDK APIs

Development strategy

Standard Linux APIs for research & development

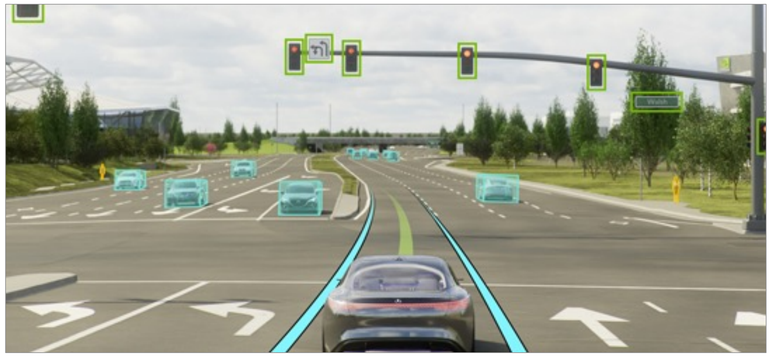
Linux Workstation / Cloud (x86)	Embedded Linux Development Target	Embedded QNX Safety Critical Target

Common DRIVE platform APIs for production deployment

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

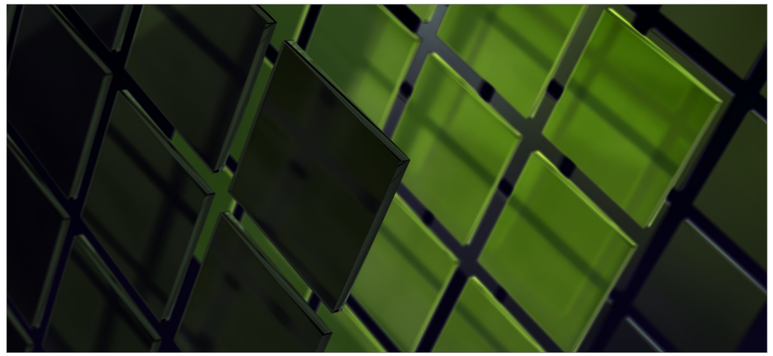
Pillars of DRIVE OS

For automated driving systems & cockpit AI



Functional Safety

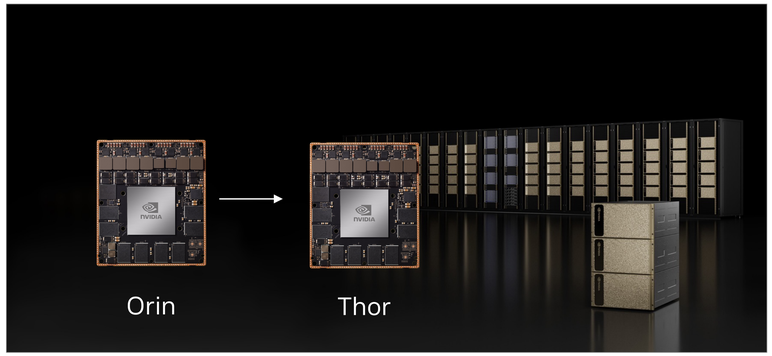
ISO 26262 certified software built with ASPICE compliance



Virtualization

Security

ISO / SAE 21434 compliant software



Common APIs From Car to Cloud

Scalability

Scalable from 30 to 2000 TOPS

SDK – Libraries and Tools

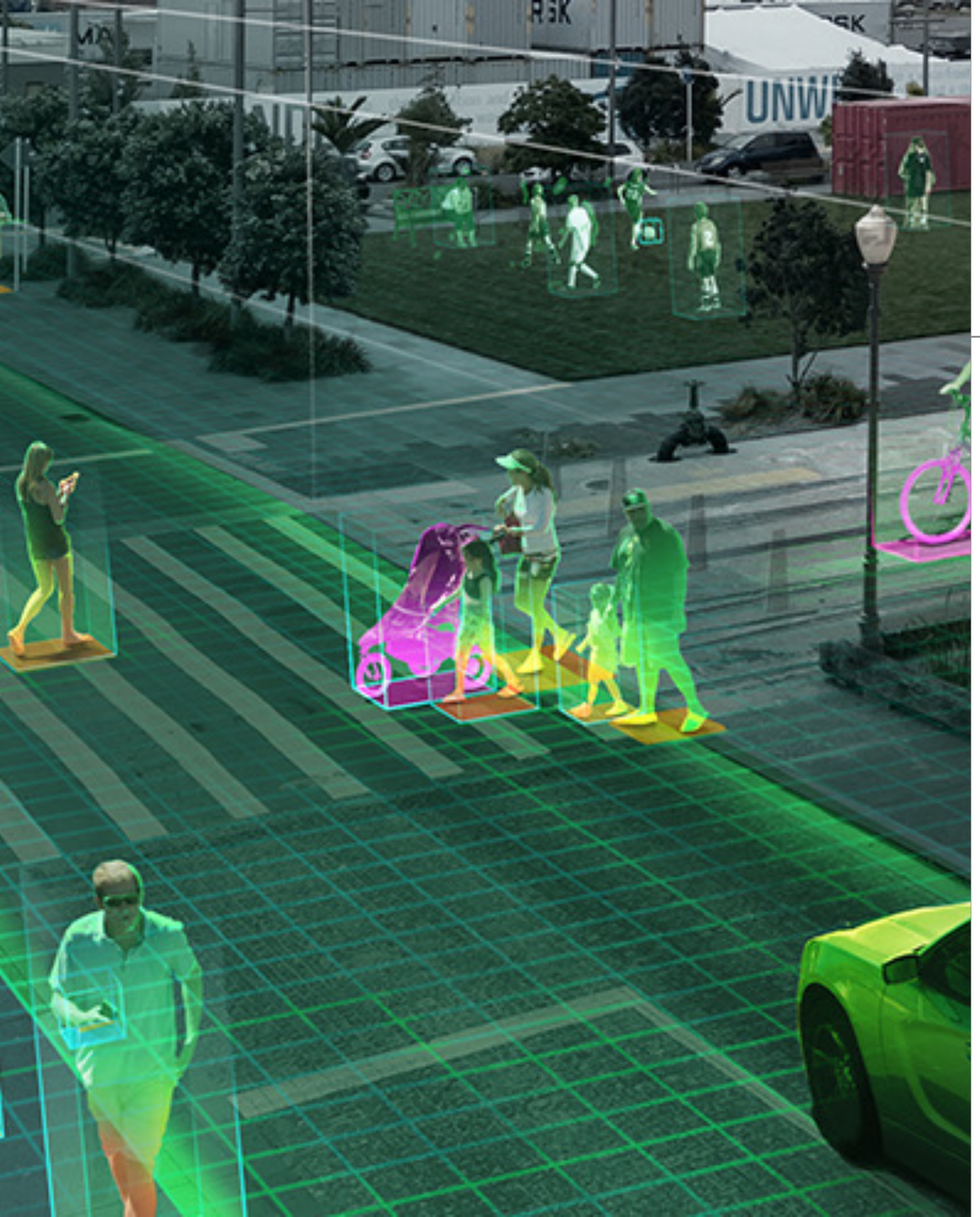
NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Why QNX for Safety?

Safety OS key selection criteria

- ISO 26262
  - ASIL D certified RTOS
  - TCL3 qualified toolchain
- POSIX PSE52 standards certification
  - Requirement for CUDA support
- Common Unix heritage with Linux
  - Rich dependent library support

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.



Path to Linux Safety

Depends on safety decomposition and criteria

- DRIVE OS QNX for Safety follows the ISO 26262 international standard for functional safety up to ASIL D
- The Linux Foundation's ELISA project focuses on Linux in Safety-Critical Systems with one of the goals being to work with certification authorities and standardization bodies to establish how Linux can be used as a component in safety-critical systems
- In September of 2021, ISO/NP PAS 8926 – "Road vehicles – Functional safety – Qualification of pre-existing software" project was approved, and is targeting publication in Q3 2023
- This will then generate changes to the 3rd edition of ISO 26262-6 and ISO 26262-8 anticipated to appear around 2025
- General industry consensus is that ASIL B will likely be the highest target for Linux
- DRIVE OS Linux with Safety Extensions provides many of the same safety features that are provided by DRIVE OS QNX Safety Services

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DRIVE OS Features Comparison

DRIVE OS QNX for safety vs. DRIVE OS Linux with safety extensions

	DRIVE OS QNX for Safety Safety Certifiable System	DRIVE OS Linux with Safety Extensions Safety-Critical System Foundation
Availability		
Guaranteed quality-of-service (NVIDIA Hypervisor)	Y	Y
Real-time Operating System (RTOS)	Y	N*
Reliability & Resilience		
Strict resource isolation (NVIDIA Hypervisor)	Y	Y
Freedom from interference (NVIDIA Hypervisor)	Y	Y
Redundancy (via Hardware Configuration)	Y	Y
Security		
Secure boot	Y	Y
Security services	Y	Y
Safety Extensions		
Safety services	Y	Y
DRAM & GPU ECC (Error-correcting code)	Y	Y
Hardware diagnostic services (Runtime IST)	Y	Y
Functional safety island (FSI) (ASIL D capable)	Y	Y
Classic AUTOSAR (for FSI)	Y	Y
Error propagation & handling	Y	Y
Microcontroller (MCU) (if included in production Hardware)	Y	Y
Classic AUTOSAR (for MCU)	Y	Y
Power management	Y	Y
Temperature & voltage monitoring	Y	Y
In-system-test (IST)	Y	Y
Fail over handler	Y	Y
NVIDIA Orin safety manual(s)	Y	Y
DRIVE OS Linux With safety extensions manual	N	Y
Safety Certification		
DRIVE OS QNX safety manual	Y	N
ISO 26262 safety certifiable	Y	N

** Real-time Ubuntu kernel patch available*

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Hardware Accelerated Compute Engines

Open | Scalable | Seamless | End-to-End

CUDA

Parallel computing model for compute intensive applications

TensorRT

SDK for high-performance deep learning inference

NvMedia

Optimized API providing direct access to hardware accelerated compute engines and sensors, support Orin new Optical Flow Accelerator, DLA, AV1 encode & decode

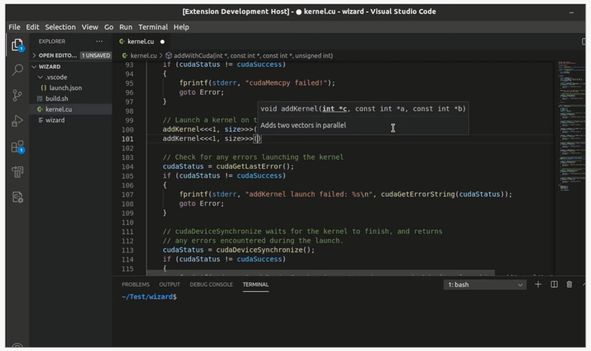
NvStreams

Highly efficient API enabling access to high-speed data transports, support over PCIe & Mellanox accelerated support across inter-ECU boundaries

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Nsight Developer Tools

For GPU and CPU software debugging and profiling

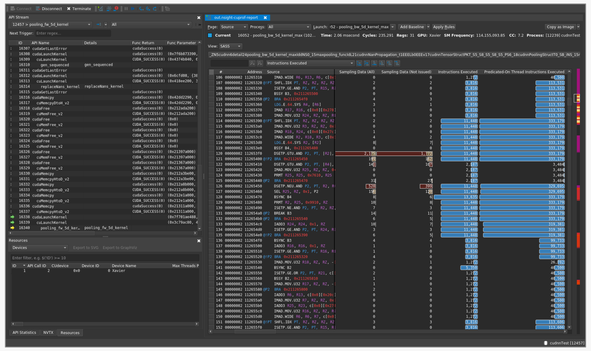


Nsight Visual Studio Code Edition

IDE GPU application development

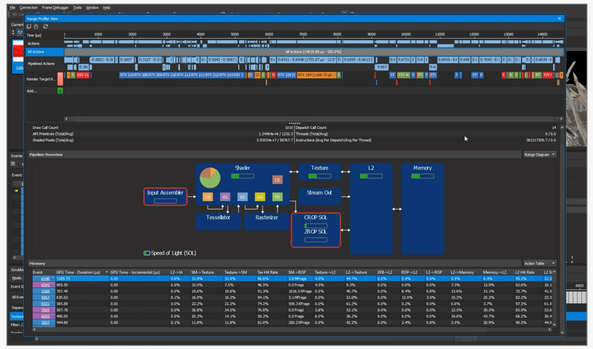
Nsight Systems

System trace



Nsight Compute

Compute profiling



Nsight Graphics

Graphics debugging & profiling

Maximized with NVTX source code instrumentation NVIDIA tools extension

NVIDIA. NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

What's New in DRIVE OS 6

General availability starting Q4 2022

- Platform APIs
  - CUDA, TRT, and cuDNN support for Orin's Ampere GPU
  - NvMedia support for the Orin's new Optical Flow Accelerator (OFA), DLA, and AV1 encode and decode
  - NvStreams support over PCIe & Mellanox Accelerated support across inter-ECU boundaries
  - Introducing Vulkan SC
- QNX Safety Services
  - DRAM ECC Patrol Scrubbing
  - Integration of Orin's integrated Functional Safety Island (FSI)
  - New streamlined Safety Services Architecture (replacing NvGuard 3LSS)
- Linux Safety Extensions
  - Introduction of some of the safety features deployed on QNX
- Developer Tools
  - Nsight Graphics support for Vulkan & Vulkan SC
  - Nsight Systems support for NvStreams, Vulkan, & Vulkan SC
  - Nsight Visual Studio Code Edition
- Security Services & Secure Boot
  - Integration of Orin's Platform Security Controller (PSC)
  - Secure boot & PKCS #11 support for Orin's additional Crypto Acceleration features

NVIDIA. NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DRIVE OS Versions

Software component versions — DRIVE OS 5 vs. DRIVE OS 6

Drive Components	DRIVE OS 5.2	DRIVE OS 6.0
Ubuntu Host Development Environment	18.04	20.04
Ubuntu Target Root File System[1]		
Linux Kernel[1]	4.14	5.10
Blackberry QNX SDP[2]	7.0.4	7.1.1
Blackberry QNX QOS[2]	2.1	2.2
QCC Toolchain	5.3	8.3
GCC Toolchain	5.4	9.3
C++ Feature set	14	17
DriveWorks	4.0	5.x
CUDA Toolkit	10.2	11.4
NVIDIA UDA CUDA Driver[1] (x86)	r450	r470
TensorRT	6.4	8.x[3]
cuDNN	7.6	8.x[3]
Vulkan	1.2	
Wayland[1]	1.18	
Vulkan SC	n/a	
QNX Screen[2]		n/a
PKCS#11	**Y**[4]	**Y**

Hardware	DRIVE OS 5.2	DRIVE OS 6.0
Xavier/Xavier DevKit	**Y**	**N**
Orin/Orin DevKit	**N**	**Y**

Sensors		
OnSemi AR0231	**Y**	—
OnSemi AR0820		**Y**[4]
Sony IMX390		—
Sony IMX728	**Y**	**Y**
Sony IMX623		
OV OV2311		

Other		
Packaging	.run files	Debian/Docker
Distribution	NVONLINE	NGC

Notes:
1. Linux only, not available on QNX
2. QNX only, not available on Linux
3. Final version number TBD
4. For development only

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DriveWorks is Built for AV Development

Proven AV Development Foundation

The Compute Graph Framework and the essential algorithms and tools DriveWorks provides are bootstrapping AV development.

Build on top of an automotive Middleware proven in practice — DriveWorks is employed at NVIDIA's AV development and at leading automotive OEMs like MB and JLR.

Built For Performance

DriveWorks provides reliable, high-throughput data transfer and highly efficient algorithms optimized for Orin's hardware accelerators.

Every millisecond counts for safety-critical applications. NVIDIA engineers have fine-tuned DriveWorks over three product generations to reach minimal latency.

Architected For Safety

Automotive safety standards are fundamental to the design of DriveWorks and enable a path to production.

Introducing safety once development has progressed to a certain point is hard–develop with DriveWorks' deterministic STM Scheduler to build with safety from the start.

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

What Sets DriveWorks Apart

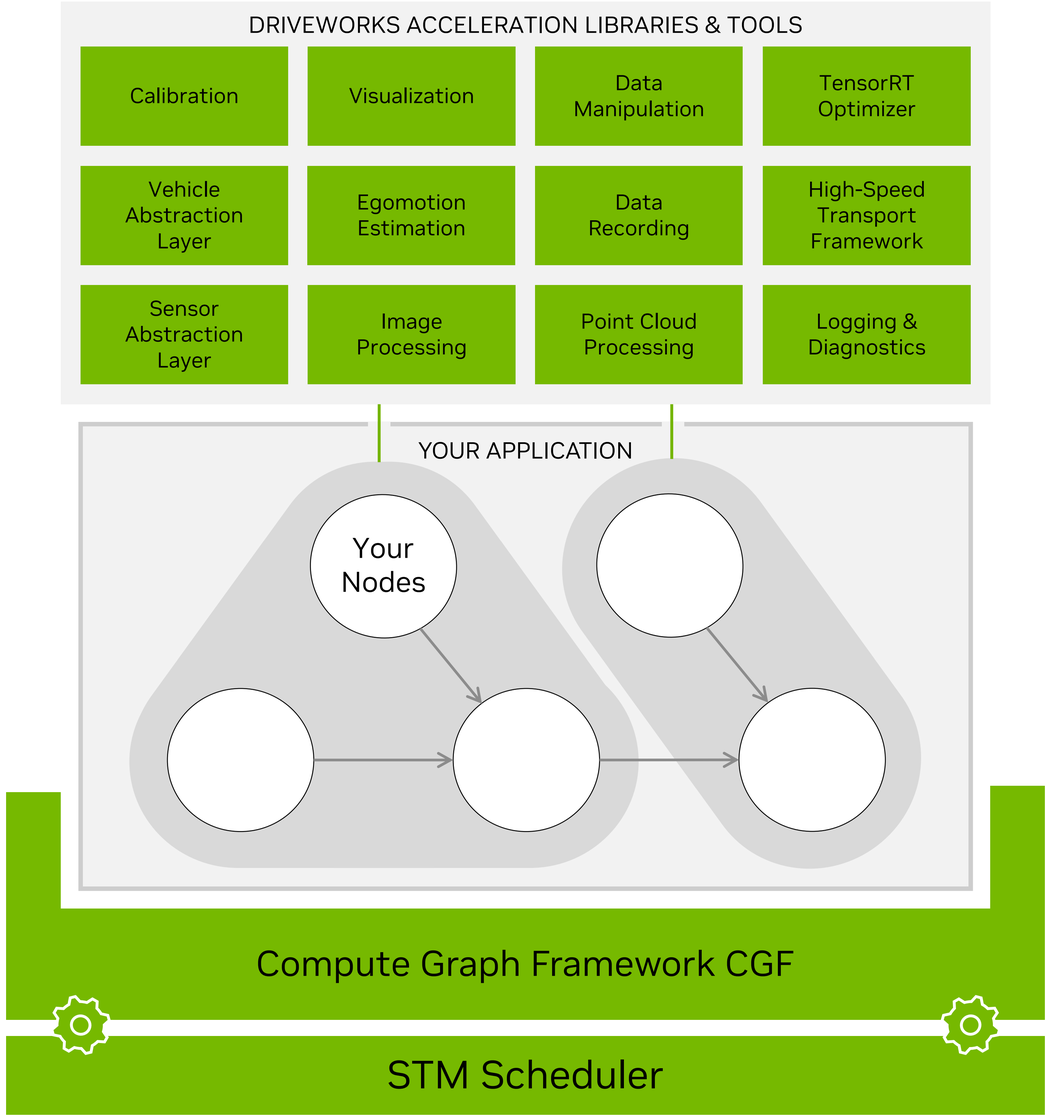
Features		DriveWorks	ROS 2
Performance	Algorithms Implemented with Efficient GPU Usage	Y	N / Y* *Subset via ROS2 with Isaac
	Support for Orin HW Accelerators PVA, VIC for Redundancy	Y	N *Subset via ROS2 with Isaac
	Zero Copies for Sensor Data Transmission Between Compute Engines	Y	N *Subset via ROS2 with Isaac
Safety & Reliability	Deterministic Scheduling	Y	N
	Path to Safety Certification	Y	N
	Used in Automotive OEM Production Software	Y	N
Support	Support by Engineers via Forum	Y	N / Y
		Optimal for automotive software development	Great for robotics optimization WIP w/ Isaac ROS

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DriveWorks — Comprehensive Middleware Solution

Rich Library of Algorithms and Tools
to accelerate your applications

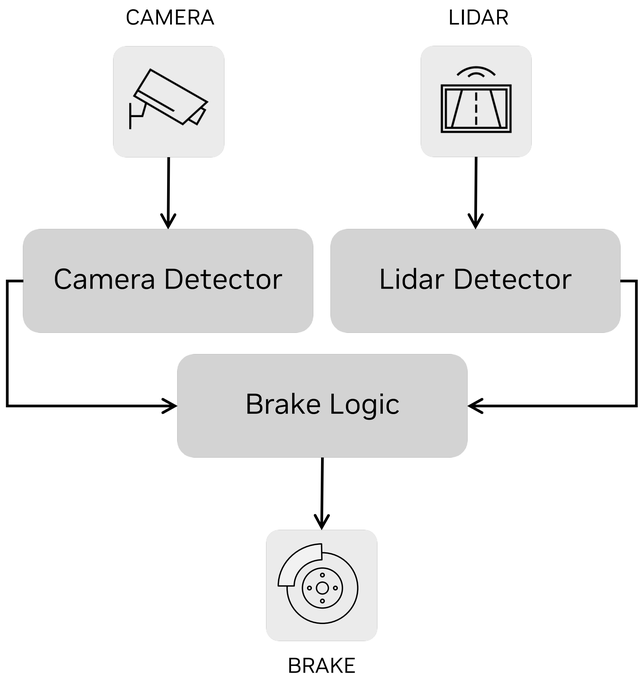
Compute Graph Framework
to leverage deterministic scheduling

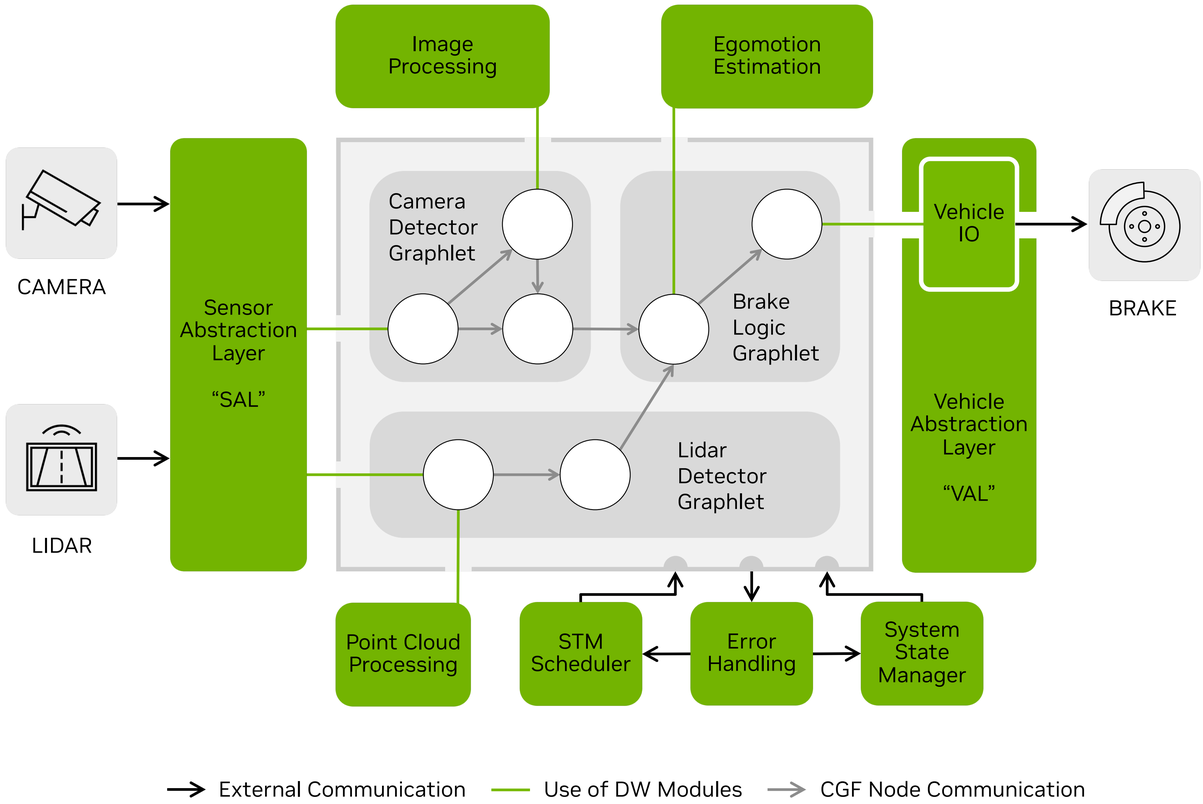


NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Exemplary Application as a Compute Graph

CGF enables structured and dependable software

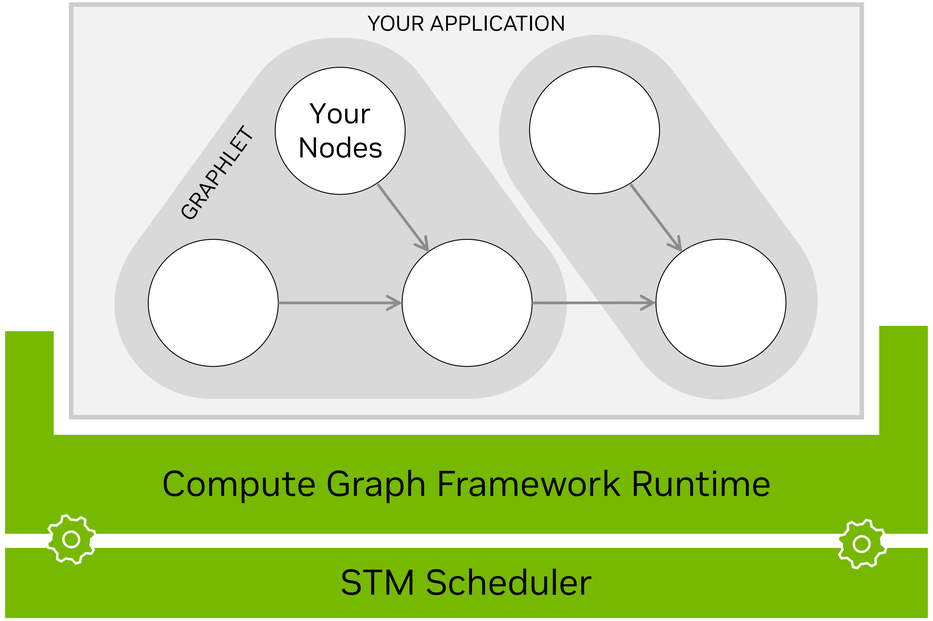




NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Deep Dive Into Compute Graph Framework (CGF)

CGF building blocks



Node c++ dwNode & .node.json

- Reusable component
- Provides Ports for data exchange
- Execution via Passes — max one pass per hardware engine (CPU core, GPU, DLA, PVA, VIP etc.)

Graphlet .graphlet.json

- Models Directed Acyclic Graph (DAG) by composing Nodes and other Graphlets and connections between them

Application .app.json

- Defines process layout
- Defines execution schedule (Passes, Frequency, WCET)
- References a root Graphlet

CGF Runtime

- Instantiates processes, initiates Nodes and connects their Ports
- Hands over execution of Node Passes to STM scheduler

STM Scheduler

- Static, non-preemptive scheduler
- Schedule compiler generates static schedules from .json descriptors

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Migrating to CGF

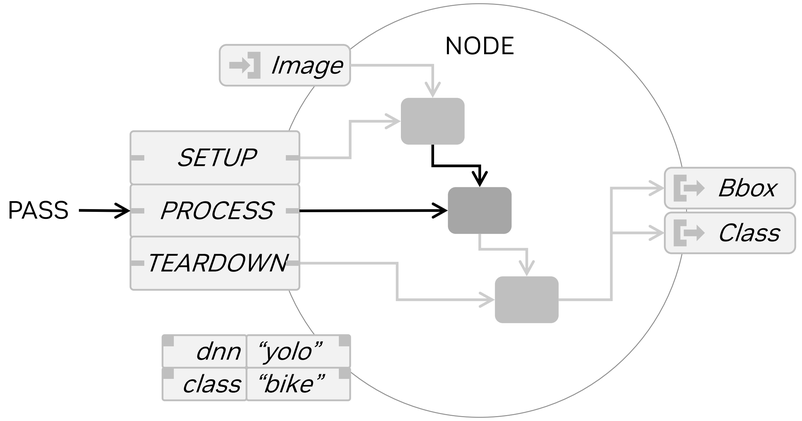
Common workloads

Refactor	1. Replace legacy middleware data structures with independent data structures
	2. Remove remaining dependencies of functional logic to legacy middleware
	3. Split API to only use one compute engine per API call
Implement	4. Implement CGF Nodes wrapping functional logic
	5. Define graph and schedule
Optimize	6. Execute Graph with STM Scheduler, benchmark, derive WCETs, optimize schedule

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Building a CGF Node

Key components and implementation



Public Node Interface MyNode.hpp

Node
Inheriting from base Node
Constructor receives parameters
Create function registers Node

```
class MyNode : public dw::framework::ExceptionSafeProcessNode
{
  MyNode(const MyNodeParams& params, ...);

    dw::framework::create<Node>(ParameterProvider& provider);
```

Ports
Inputs/Output ports specifying data type and unique port name

```
    static constexpr auto describeInputPorts(){...};
    static constexpr auto describeOutputPorts(){...};
```

Passes
Passes to be executed in order, on specified compute engine

```
    static constexpr auto describePasses(){
        return dw::framework::describePassCollection(
            dw::framework::describePass("SETUP", DW_PROCESSOR_TYPE_CPU),...)};
```

Parameters
Parameters for the constructor

```
    static constexpr auto describeParameters(){...};

}
```

Implementation MyNode.cpp

Ports
Initialize ports, prepare output data containers

```
void MyNodeImpl:initPorts(){
    NODE_INIT_INPUT_PORT("IMAGE"_sv);
    ...
}
```

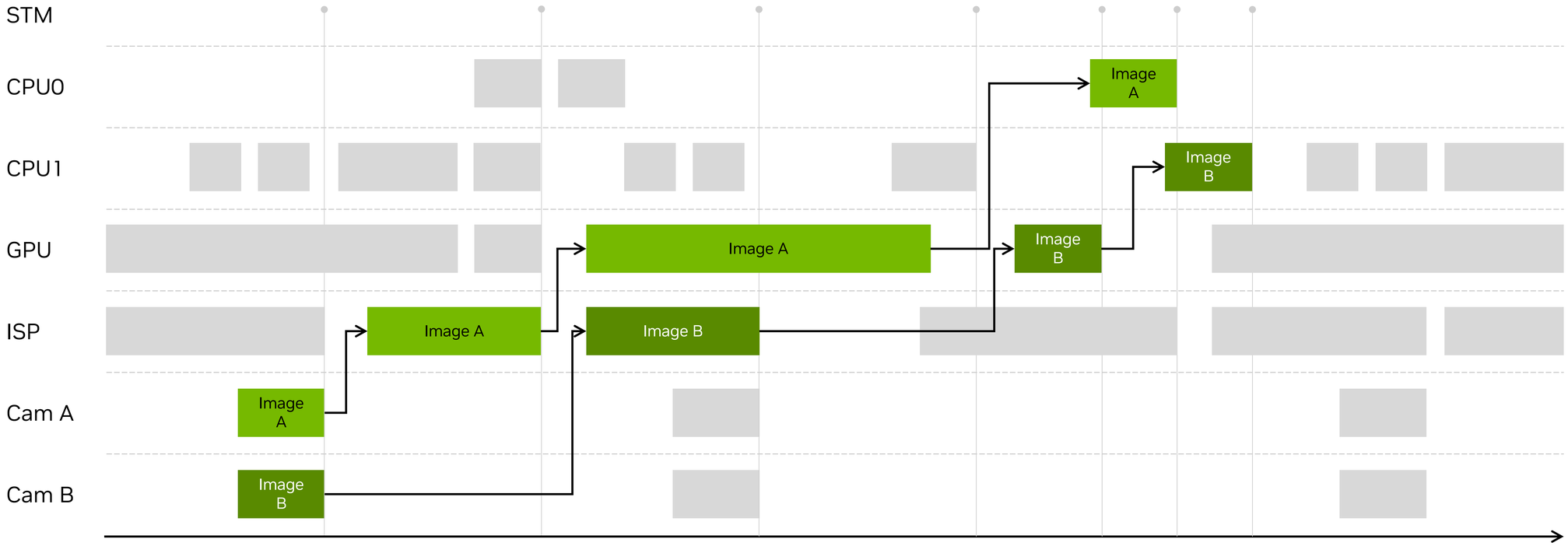
Passes
Register methods used for passes defined in public interface
Implementation of the passes

```
void MyNodeImpl::initPasses(){
    NODE_REGISTER_PASS("PROCESS"_sv, [this]() { return process(); });...}

dwStatus MyNodeImpl::process(){...}
```

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Schematic STM Schedule



The STM Scheduler orchestrates the deterministic execution of applications across compute engines

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DriveWorks Modules

A rich library of algorithms and tools to bootstrap AV development

Optimized Implementations of Common Computer Vision Algorithms for Orin's GPU, PVA & VIC Accelerators

Ego Vehicle Relative Motion Estimation from Sensor Data

GPU-Accelerated Point Cloud Processing: ICP, Stitching & More

Input Format Conditioning & DNN Lifecycle Management

Visualization of Sensor Data Recordings

Tools to Manipulate Recordings: Integrity Verification, Chopping, Video Export and More

ALGORITHMS

- Point Cloud Processing
- Image Processing
- Dynamic Calibration
- Egomotion Estimation

FRAMEWORKS

- DNN Framework
- High-Performance Data Channels

SENSOR & VEHICLE ABSTRACTION

- Sensor Abstraction Layer
- Vehicle Abstraction Layer

TOOLS

- Data Recording and Replay
- Recording Visualization
- TensorRT Optimizer
- Recording Post Processing
- Sensor Tools
- Static Calibration

Abstraction Layer Enables Plug & Play Sensor Interfacing

Vehicle IO & Vehicle Configuration Management

Offline Calibration for Vehicle Sensors

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Sensor Abstraction Layer (SAL)

Generalize sensor interfaces with abstraction details

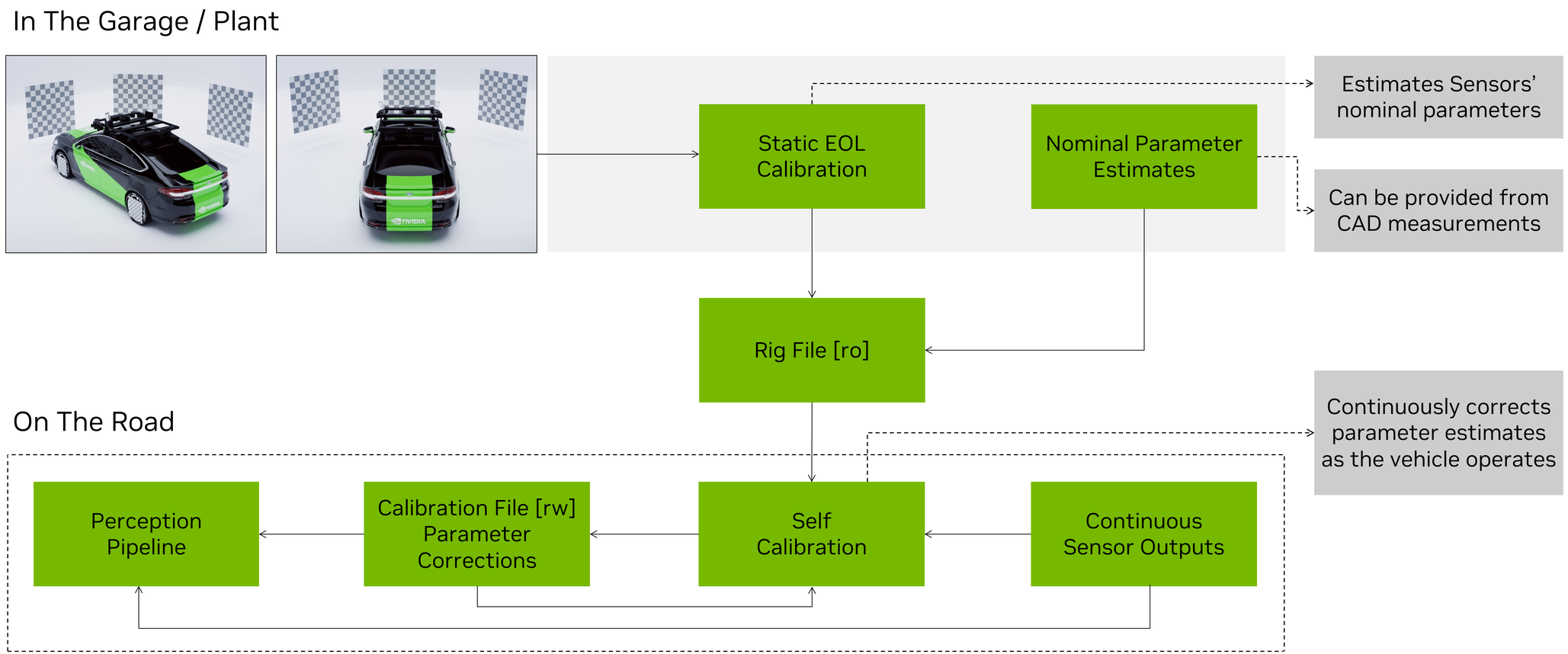
- Provide hardware sensor abstraction and virtual sensors for replay
- Provide raw sensor serialization for recording
- Provide seeking capabilities for virtual sensors
- Abstract platform and software particularities
- Exploit hardware engines to improve the processing (H264 / H265 codec, VIC…)
- Support wide variety of sensors out-of-the-box
- Support custom sensors via plugin framework

Sensor Type	Camera	Radar	Lidar	CAN	GNSS / IMU	Ultrasonic
Abstraction Details	• Leverages DRIVE AGX ISP engine for image processing • Native outputs (RAW or YUV / RGB) • CUDA outputs (RAW, RGBA, YUV) • Embedded lines with parsing • Synchronized captures • Basic sensor statistics • Supports IR cameras • Custom camera support	• Ethernet and CAN (TCP / UDP) radars • Short, medium and long range • Egomotion feedback to sensor • Detections and tracks • Basic sensor statistics	• TCP and UDP based lidars • Rotational or planar scanners • Basic sensor statistics • Extend point cloud formats to support velocity, color, etc. • Dynamic control	• Supports Socket CAN and Aurix CAN • DBC interpreter encoder / decoder • CAN filters	• CAN based IMU • Ethernet based GNSS, NMEA and proprietary protocol • Supports basic sensor statistics	• Coming soon

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Sensor Calibration

Fidelity | Consistency | Real-time



NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Real-Time Sensor Recording & Replay Tools

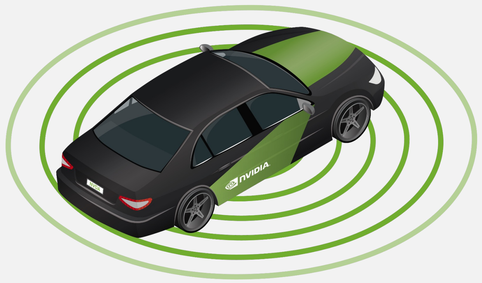
Record | Synchronize | Playback |
Time stamp | Data integrity validation

- Sensor output saved to system's data storage devices, including SATA/USB 3.0
  - Tuned performance to avoid glitches during capturing and recording
- Compressed / uncompressed, synchronized and time stamped sensor data capture
- Supports distributed and high throughput recording use cases
- Recording post-processing tools provided for convenience:
  - Verification of configuration and integrity of each recording session
  - Support for fast seeking in recorded files
  - Recording clipping, conversion and time alignment tools
  - Replayer tool for inspection

NVIDIA. NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DriveWorks Sensor Related Development Flow

Capture Data (Live Sensors)

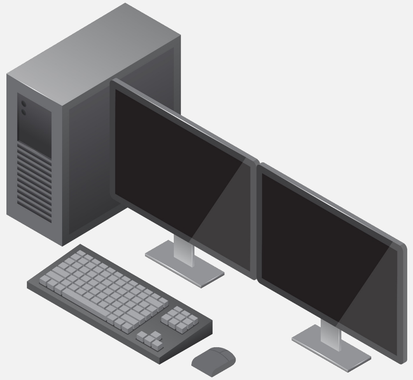


DriveWorks Tools

- Sensor calibration tools
- Recorder — sensor data & logs

Recorded Data →

Post-Process Data



DriveWorks Tools

- Postrecord checker
- Replayer
- Chop
- Exporter

Post-processed Data →

Develop & Test (Live & Virtual Sensors)

DriveWorks SDK

- Modules & samples (SAL, image & point cloud processing, compute graph framework, DNN framework, calibration, egomotion)

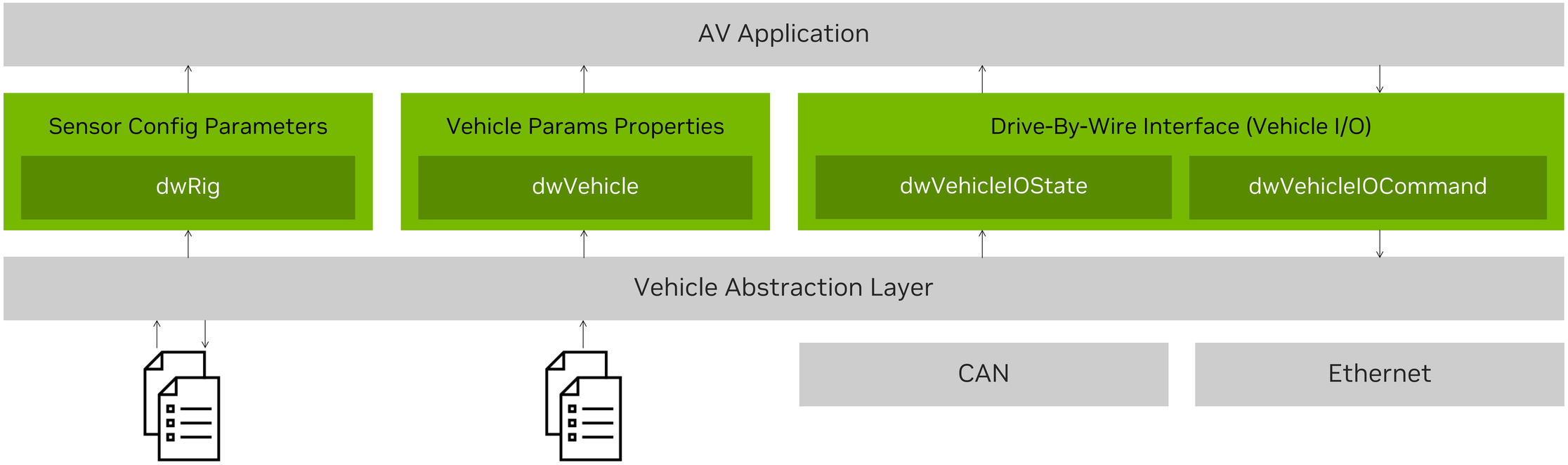
Deploy & continuous improvement

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Vehicle Abstraction Layer (VAL)

Scalability across vehicle models and OEMs

- Provides unified configuration infrastructure for multi sensor configurations and vehicle properties
  - **dwRig**
  - **dwVehicle**
- Provides extendable interfaces and APIs to receive state and send actuation commands
  - **dwVehicleIO**



NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DNN Framework

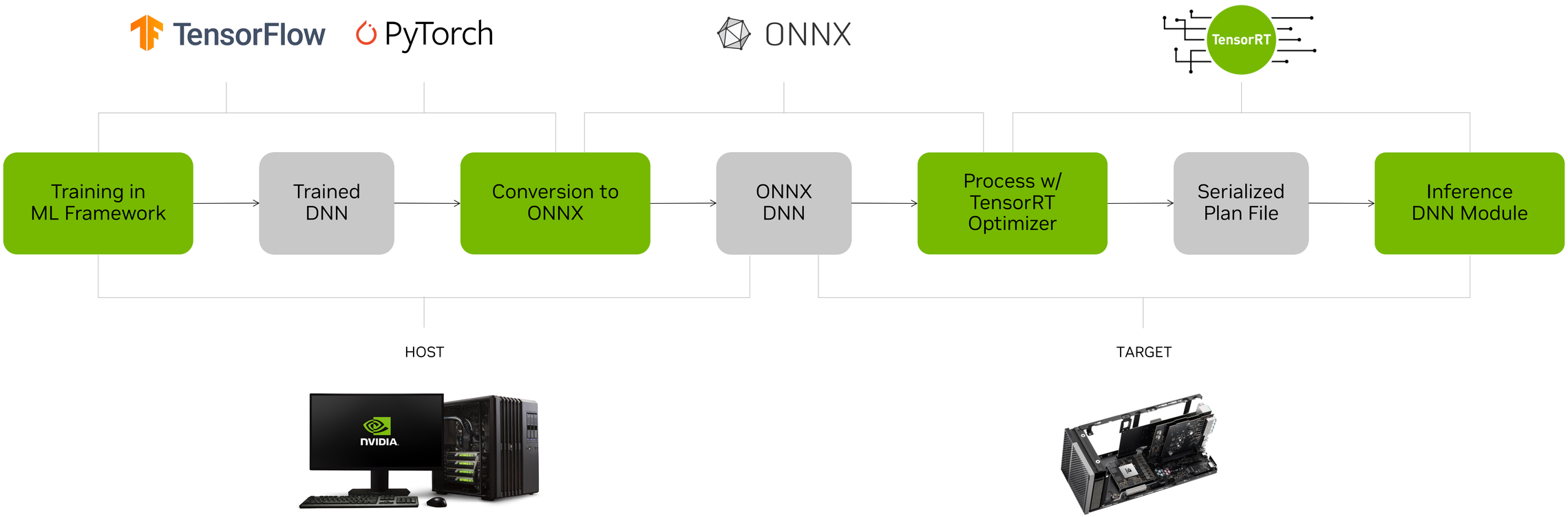
Reduces time to develop inference-based AV applications

TensorRT Optimization Tool	Data Conditioner Module	DNN Module	Clusterer Module
Enables optimization for a given pretrained Caffe or ONNX model using NVIDIA TensorRT	Used in support of the DNN module, adjusts input data to the network input format	Implements inference of deep neural networks that were generated with the DriveWorks TensorRT optimization tool	Implements DB SCAN clustering algorithm that groups bounding boxes by similarity between bounding calculated by intersection over union

- Provides lightweight framework to manage DNN lifecycle
  - Preprocessing → Inference → Postprocessing
- Optimizes DNNs with NVIDIA TensorRT
  - Can be used with DNNs provided with DRIVE Software or those that have been independently trained
  - DNN Plugins enable optimization of layers not directly supported in TensorRT
- Supports x86 and DRIVE AGX-based workflows
- Deploy on DRIVE GPU and DLA engines with just parameters change

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DNN Inference Workflow on Drive AGX Orin



NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Image & Point Cloud Processing Modules

Highly optimized computer vision & point cloud processing algorithms for DRIVE platform

- Growing collection of commonly used algorithms for AV use cases
- Accelerated for real-time performance
- Hardware & software abstraction
  - Compatible with the SAL data structures, abstracting away sensor specifics
  - Deploy on DRIVE GPU and PVA engines with just parameter change
- Modular design

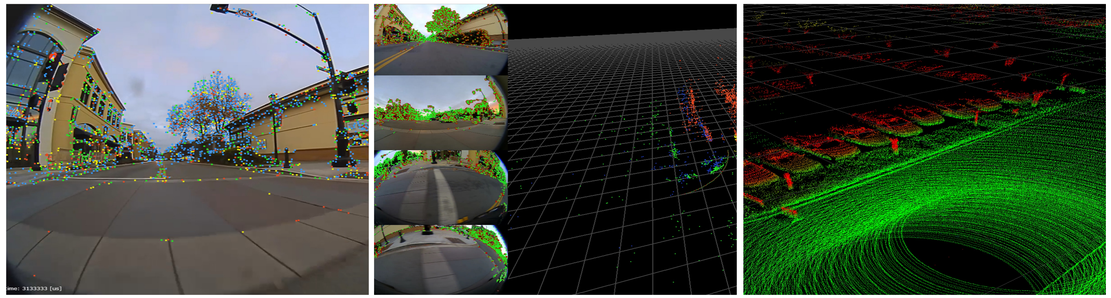


Image Processing Modules	Algorithms	Hardware Engines
Features	Harris Corner Detector, FAST9 Corner Detector	GPU, PVA
Filtering	Pyramid, Threshold, Image Filtering	GPU, PVA
Tracking	Template Tracker, KLT Tracker, Box Tracker	GPU, PVA
Geometry	Image Transformation, Rectification, Pose Estimation	GPU, VIC
Dense Optical Flow	Dense Optical Flow	PVA, VIC, ENC
Structure from Motion	Structure from Motion	GPU
Stereo	Stereo Rectification, Disparity estimation	GPU, PVA
Connected Components Labeling	Connected Components Labeling	GPU
Color Correction	Multi-camera Color Correction	GPU

Point Cloud Processing Algorithms	Description	Hardware Engines
Accumulation	Accumulate decoded packets to a lidar spin according to specified properties	GPU
Stitching	Stitch multiple point clouds in a common coordinate system	GPU
Range Image Creation	Generate 2D image from accumulated point clouds	GPU
ICP	Align 3D points from a pair of lidar spins via Point-Plane Iterative Closest Points implementation	GPU
Plane Extraction	Estimate one 3D plane	GPU
Filter	Point cloud filter to filter out invalid points	GPU

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Egomotion

Ego vehicle relative motion estimation from sensor data

Input

- Odometry measurements from VAL: dwVehicleIOState
- IMU measurements from SAL: dwIMUFrame
- Radar measurements from SAL: dwRadarScan (optional)

Output

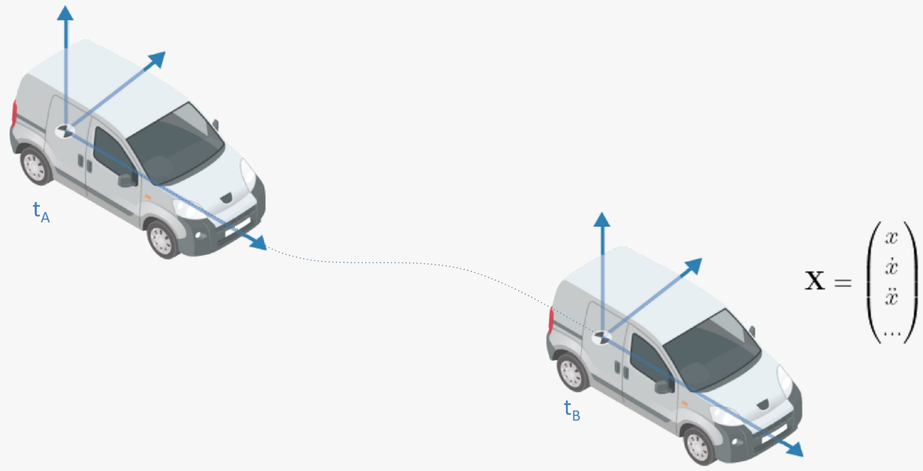
- Instantaneous state of the vehicle: dwEgomotionResult (orientation, linear velocity + acceleration, angular velocity)
- Relative transformation between any 2 timestamps as dwTransformation (interpolates into the past, limited extrapolation into the future)
- Uncertainty estimates

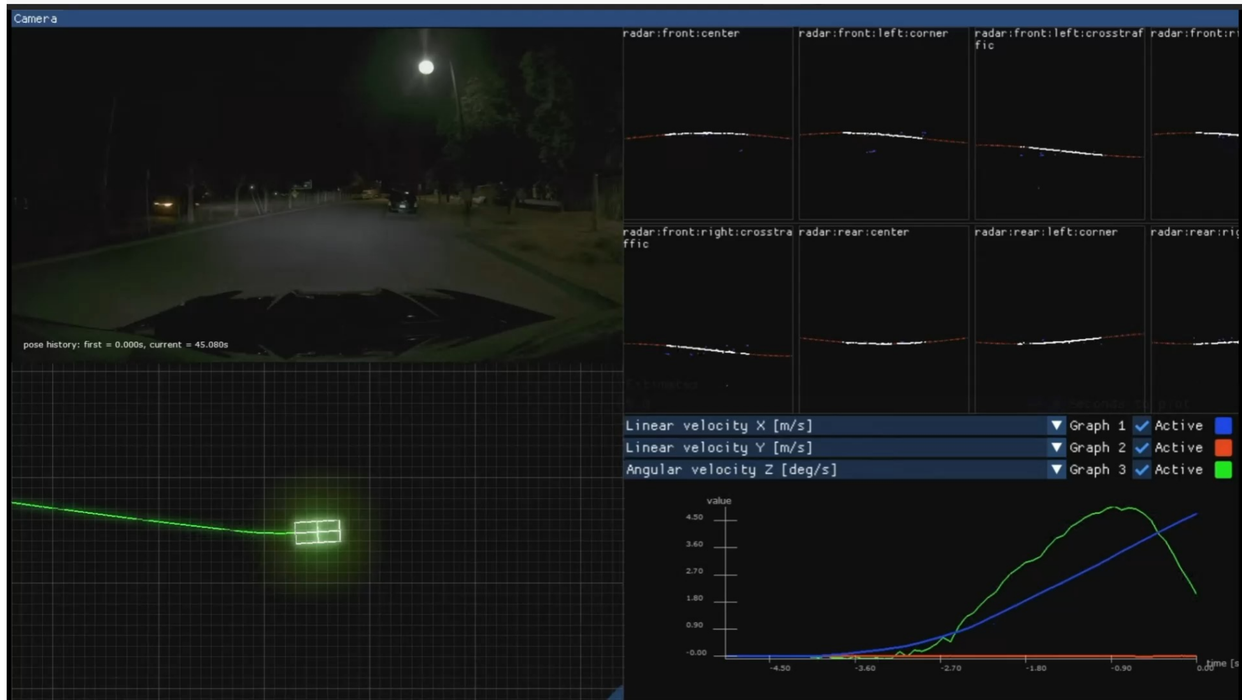
Notes

- Targeting ASIL D for full 6DoF in presence of 2 IMUs at ASIL B(D), wheel speed signals at ASIL B(D), steering angle signal at ASIL D
- Low-speed (parking) can use multi-radar as speed source to bridge wheel tick sensor dead band
- Suspension modeling for low error in pitch / roll

Performance

- CPU implementation for IMU egomotion (radar / lidar / camera GPU)





NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Get Started with DRIVE SDK

Extensive documentation & training material available on NVIDIA Developer

Learn More

- Visit the DRIVE training page for webinars and other resources
- Check out information related to DRIVE Hyperion, DRIVE AGX Orin and DRIVE SDK

Get Access

- Join the DRIVE AGX SDK Program on NVIDIA Developer
- Read DRIVE OS and DriveWorks documentation at https://developer.nvidia.com/drive/documentation
- Download DRIVE OS which includes DriveWorks, NvMedia, CUDA, cuDNN and TensorRT at https://developer.nvidia.com/drive/downloads

Contact Us

- Contact the NVIDIA automotive team at https://www.nvidia.com/en-us/self-driving-cars/self-driving-cars-contact-us
- Ask questions and get support from the Forum Team at https://forums.developer.nvidia.com/c/autonomous-vehicles/drive-agx-orin/520

Develop and Test

- Use the DRIVE OS and DriveWorks numerous sample applications as a starting point for development

Share Your Work

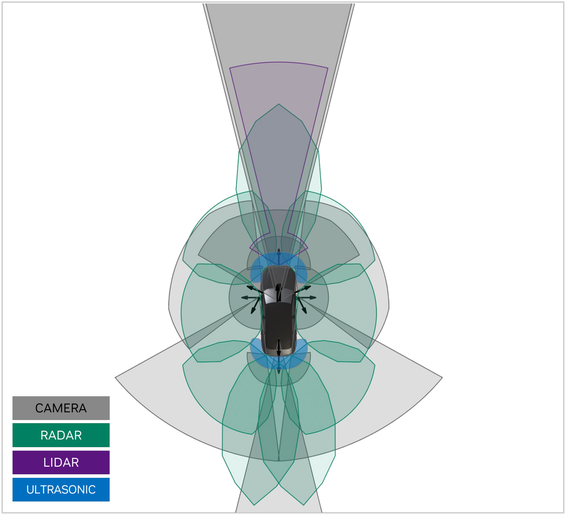
- Get your work featured on the NVIDIA DRIVE partner page (https://www.nvidia.com/en-us/self-driving-cars/partners)

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

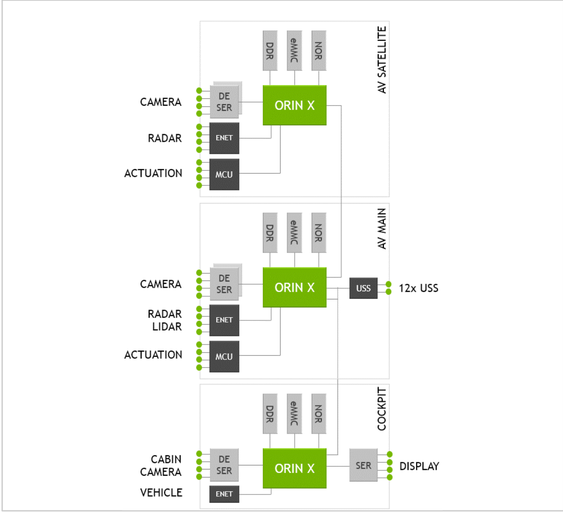
DRIVE Sensor Support

DRIVE Hyperion 8.1 DevKit

Complete sensor suite & high-performance AI computing

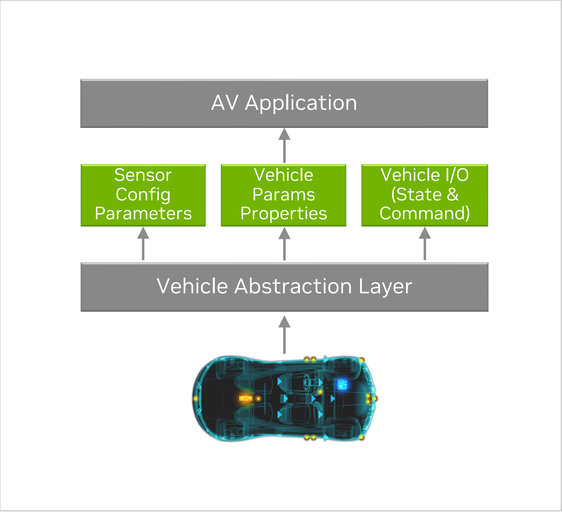


AV Sensor Set & Stack



FUSA Computer Architecture

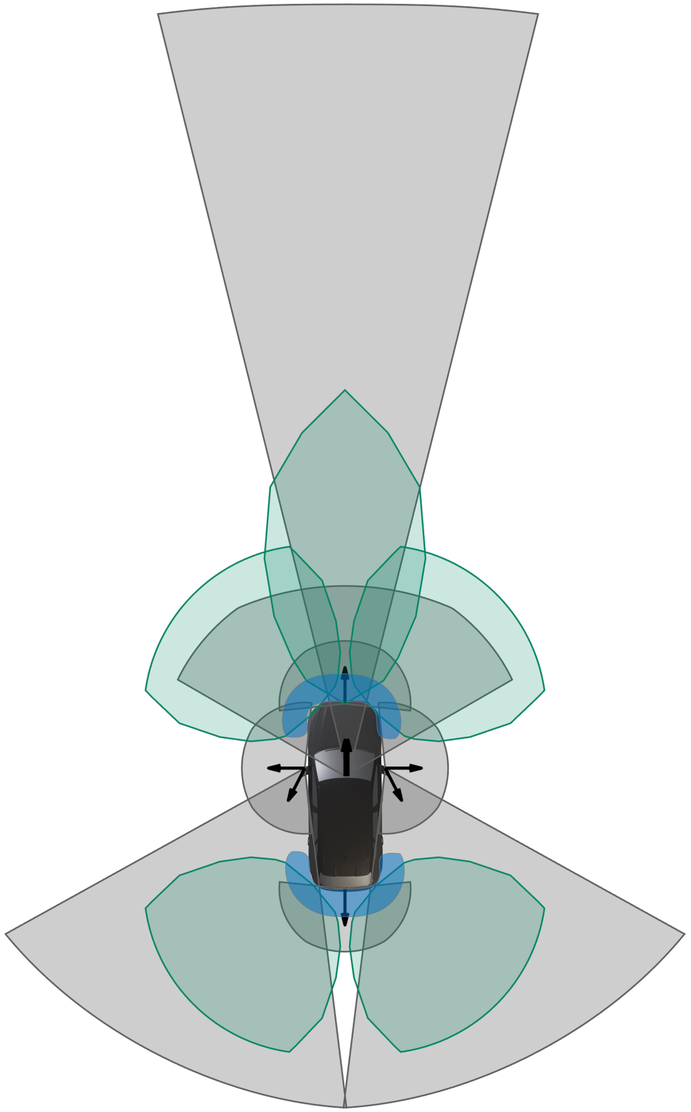
4D Data Collection



Adaptation Tools

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Hyperion 8.1 Sensors Base (L2+)



	Type	Sensor Name	IO	Sensor Part	Details	HFOV
AV	Camera	Front Wide	GMSL2	Sony IMX728	8.3MPix RS RGGB	120
	Camera	Front Tele				30
	Camera	Side Rear Left				70
	Camera	Side Rear Right				
	Camera	Front Fisheye		Sony IMX623	3MPix RS RGGB	200
	Camera	Rear Fisheye				
	Camera	Left Fisheye				
	Camera	Right Fisheye				
	Radar	Front Center	ETH	Conti ARS620	MR 100BaseT1	120
	Radar	Corner Front Left		Hella SRR Gen6		160
	Radar	Corner Front Right				
	Radar	Corner Rear Left				
	Radar	Corner Rear Right				
	Ultrasonic	Ultrasonic x12	DSI3	Valeo USV10		75
	IMU	Vehicle IMU	CAN	Conti SC13S		-
	GPS	Vehicle GPS	ETH	U-blox F9K		-
IX	Camera	Driver Monitoring	GMSL2	OVT OV2311*	2MPix GS IR	50
	Camera	Front Occupant Monitoring		OVT OX05B1S	5MPix GS RGB-IR	170
	Camera	Rear Occupant Monitoring				
	Radar	In Cabin	CAN-FD	Vayyar*		140

IX CAMERA

AV CAMERA

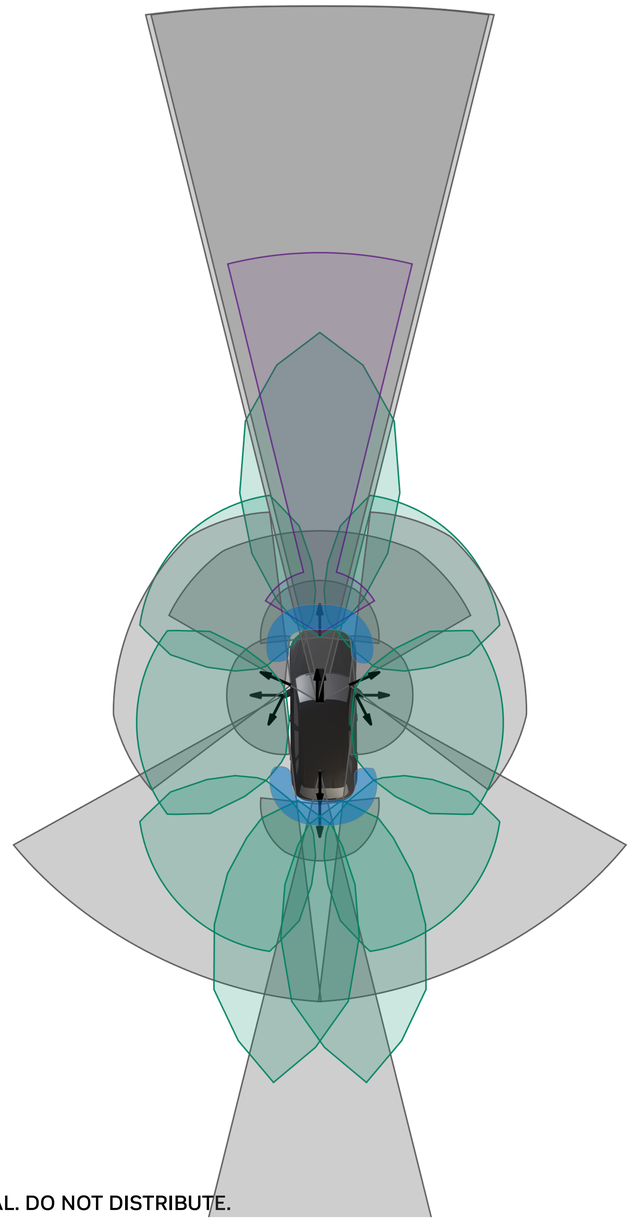
RADAR

ULTRASONIC

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

*Subject to change—working thru final specifications with vendors

Hyperion 8.1 Sensors High (L3)



IX CAMERA
AV CAMERA
RADAR
LIDAR
ULTRASONIC

	Type	Sensor Name	IO	Sensor Part	Details	HFOV
AV MAIN	Camera	Front Wide	GMSL2	Sony IMX728	8.3MPix RS RGGB	120
	Camera	Front Tele				30
	Camera	Side Rear Left				70
	Camera	Side Rear Right				
	Camera	Front Fisheye		Sony IMX623	3MPix RS RGGB	200
	Camera	Rear Fisheye				
	Camera	Left Fisheye				
	Camera	Right Fisheye				
	Radar	Front Center Imaging	ETH	Conti ARS540	LR 100BaseT1	120
	Radar	Corner Front Left		Hella SRR Gen6		160
	Radar	Corner Front Right				
	Radar	Corner Rear Left				
	Radar	Corner Rear Right				
	Ultrasonic	Ultrasonic x12	DSI3	Valeo USV10		75
	IMU	Vehicle IMU	CAN	Conti SC13S		-
	GPS	Vehicle GPS	ETH	U-blox F9K		-
AV SATELLITE	Camera	Front Tele Satellite	GMSL2	Sony IMX728	8.3MPix RS RGGB	30
	Camera	Rear Tele				
	Camera	Cross Left				120
	Camera	Cross Right				
	Radar	Side Left	ETH	Hella SRR Gen6		160
	Radar	Side Right				
	Radar	Rear Left		Conti ARS620	MR 100BaseT1	50
	Radar	Rear Right				
	Lidar	Front Center		Luminar Slim		120
	IMU	Vehicle IMU Satellite	CAN	Bosch MMP2.11		-
IX	Camera	Driver Monitoring	GMSL2	OVT OV2311*	2MPix GS IR	50
	Camera	Front Occupant Monitoring		OVT OX05B1S	5MPix GS RGB-IR	170
	Camera	Rear Occupant Monitoring				
	Radar	In Cabin	CAN-FD	Vayyar*		140

*Subject to change—working thru final specifications with vendors

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Data Collection Sensors

Ensure high integrity 4D GT

Device	Type	Details
Ground Truth Top Lidar	HesaiTech P128	0.1° Horizontal Resolution 0.125° Vertical Resolution Up to 200m
Ground Truth INS	Novatel PwrPak7D-E1	5cm RTK Accuracy Dual antenna

High fidelity 4D GT sensors verify & validate existing cameras, radars, lidar, & IMU to ensure perception results accuracy & robustness

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

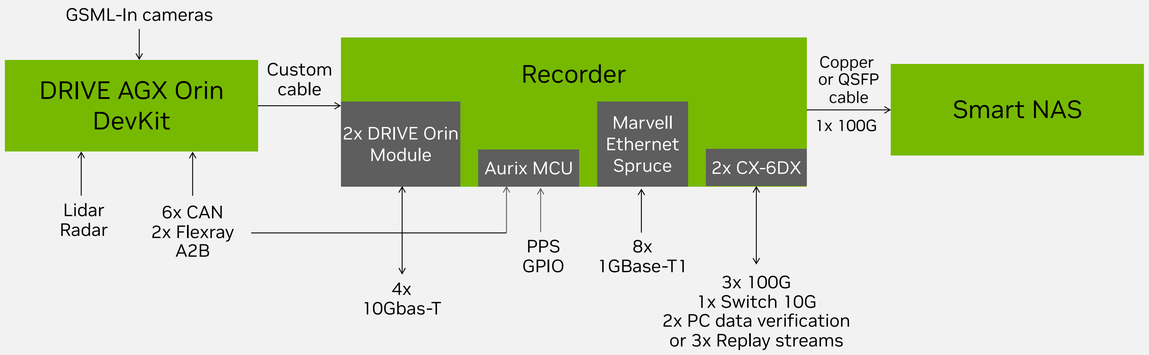
Hyperion 4D GT Recorder

Best performing compute box to offload data record and replay

Offloads Sensor Data Record & Replay

- Record & replay platform for DRIVE Hyperion 8.1 sensors
  - Capture raw data from sensors along with output control data and encode for external storage
  - Replay encoded data from external storage and decode it for simulation
- Each recorder has 2x Orin SoC & 2x Mellanox CX6-DX with dual 100G QSFP28 port
- Each Orin connects to each of CX6-DX via 4x PCIE Gen4 (8 GB/s)
- Dedicated Marvell Spruce to PTP sync
  - SoCs & connected sensors
- Supports DRIVE OS Linux
- Early access: October 2022
- General access: December 2022

Vehicle Setup Flow

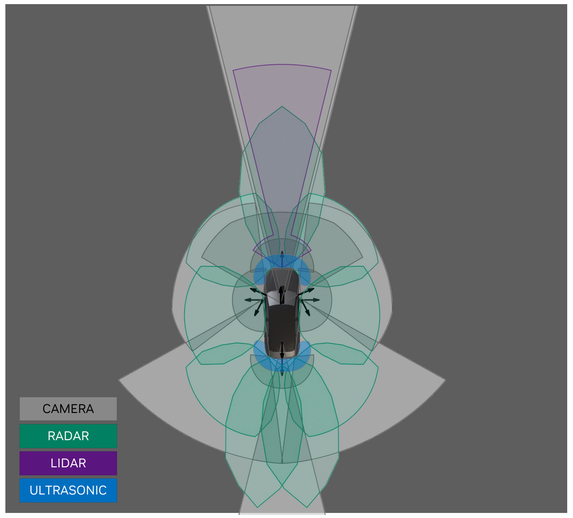


- Recorder I/O
  - 3x Harness for CAN / Flexray / A2B / GPIO
  - 8x 1 GbE-T1 H-MTD
  - 4x 10 GbE RJ45
  - 4x 100 GbE QSFP
  - 2x DisplayPort 1.4
  - 4x Host USB A, 1x Recovery USB C
  - Debug Micro-USB
  - Antenna
- Smart NAS
  - Efficient & scalable storage solution with CPU offload support (Bluefield2- based)
  - > 2 GB/s lossless data recording storage bandwidth guaranteed
  - Data encryption support
  - Supports RDMA & NVMe-oF
  - 4x M.2 NVMe SSDs
    - Hot-pluggable
    - 4x PCIE Gen3 lanes

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Hyperion Advantage

Providing state-of-the-art advances for data collection, development and testing, minimize partner R&D and accelerate SOP

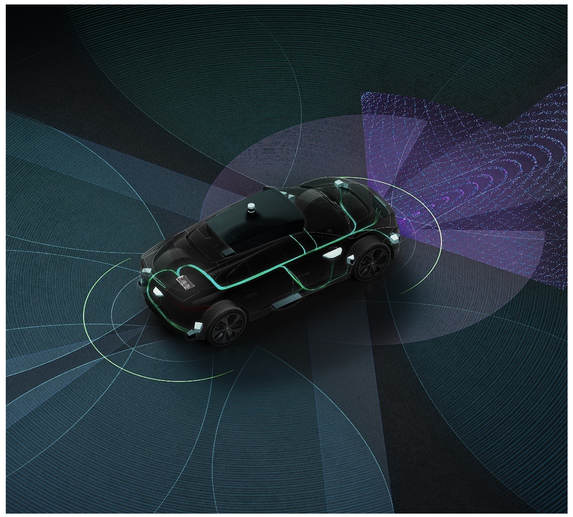


Safety & Security Certified L2+/L3 Multi-sensor AV + IX Architecture

Required sensor coverage, redundancy to meet safety, security goals

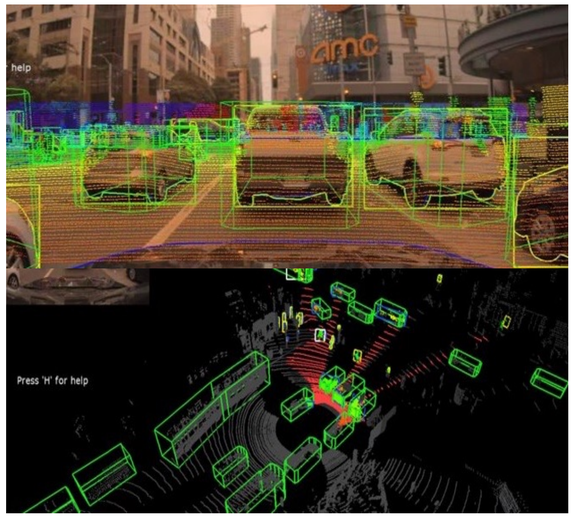
Fully Validated & Tuned Sensor Drivers

Production validated sensor tuning, safety driver, E2E sensor authentication and security solution



Access To Sim Sensor Models & Hyp8 Infra

Unblock developers to focus only on algorithms development



4D Data Collection For Efficient E2E Development

Simultaneously capture multi-sensor data to generate high quality diversified 4D GT

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Safety and Security Engineered Architecture

Hyperion 8.1 fully compliant with global safety and security standards

- ISO 26262: Road vehicles — Functional safety
- ISO 21448: Road vehicles — Safety of the intended functionality
- ISO 21434: Road vehicles — Cybersecurity engineering
- ISO 24089: Road vehicles — Software update engineering
- UNECE R79 and R157: Defines min detection range and impact on operational speed + fallback conditions
- NCAP 2023 proposal: Full suite of test covering scenarios for “5 Star”
- UNECE VMAD / IAMTS: Virtual sensor model validation
- China automotive cybersecurity regulations

Regulatory Standards

100 Engr Years

System Safety

600 Engr Years

Cybersecurity

300 Engr Years

Large safe and secure HW & SW investment
~1000 engineer years

NVIDIA. NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Production Tuned and Validated Sensors

Optimal sensor tuning & certified safety driver aiming for robust functionality

50 Engr Years

Tuning and Optimization

- Safety certified driver implementation
- Sensor authentication and diagnostics
- IQ tuning, HDR linearity and exposure settings
- Mechanical guideline and tolerances for production development and data collection

100 Engr Years

Test and Validation

- Sensor evaluation and selection
- Sensor maturity from A sample to production
- Mechanical checkout
- Functional, conformance, performance and stress test
- Car integration, validation and testing guidelines

Saving **~150 engineer years** for best performing sensor suite to achieve L3 autonomy

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Hyperion 8.1 Sensor Models in DRIVE Sim

Ray tracing based sensor models

Camera	Radar	Lidar	Ultrasonic

Hyperion 8.1 Sensors

DRIVE Sim directly supports all Hyperion 8.1 sensors, ready from **day 1**

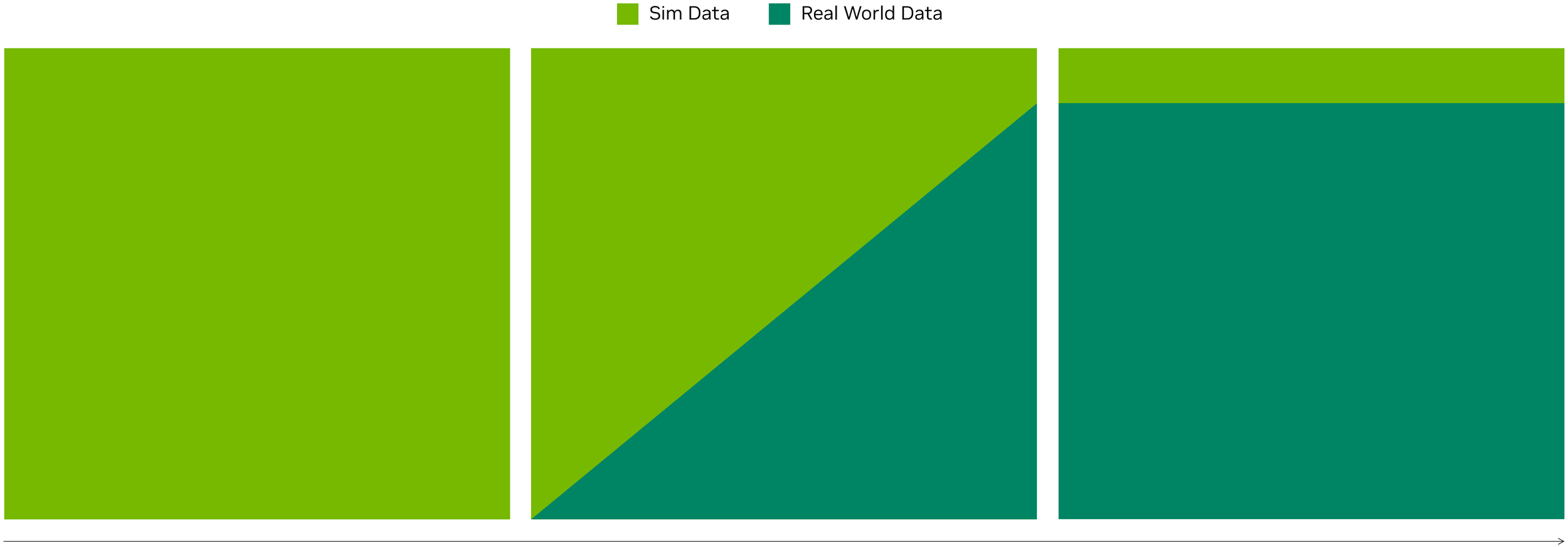
Other Sensors

6~12 months per sensor depending on whether deciding to configure model parameters from supported sensor list or custom new sensor type from scratch

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Accelerating Perception Development with Sim

Sim first - 3 phase approach for fastest time to production



Phase 1
Rapid DNN Development
Only synthetic data | Generated from Sim

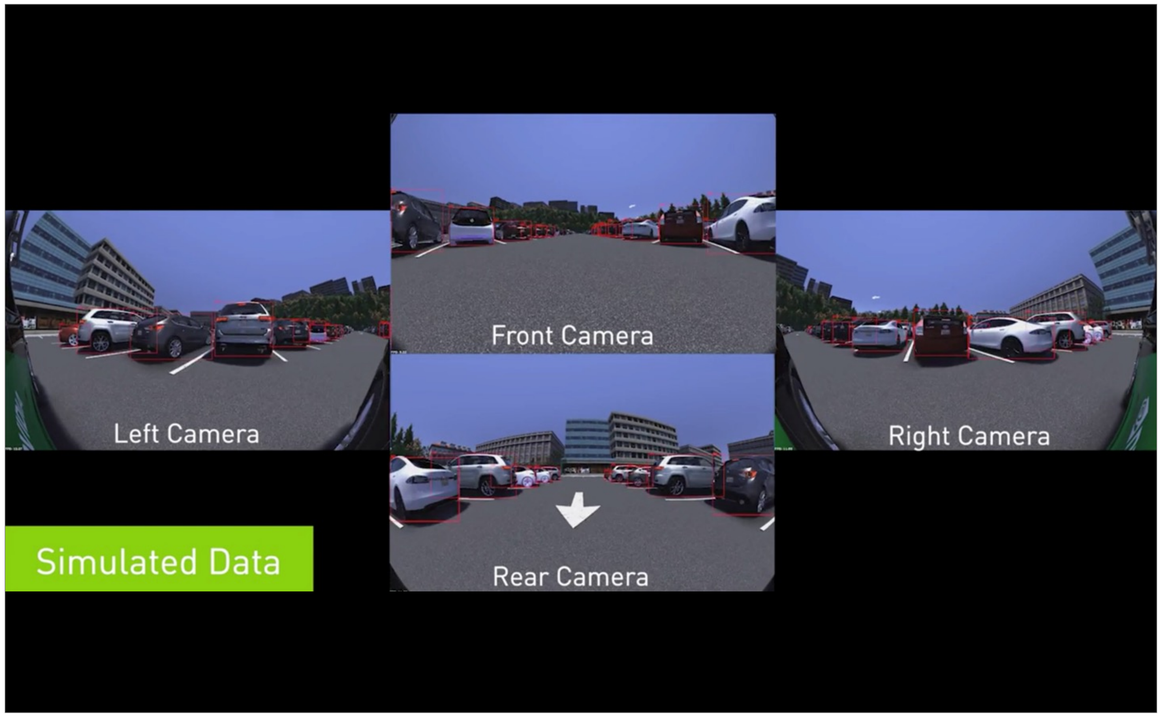
Phase 2
Scale DNN Development
Train on hybrid dataset

Phase 3
Optimize Production DNNs
Optimal sim/real dataset mix

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Simulation Use Case

Efficiently bring up new sensors & new AI models, full stack in DRIVE Sim



Train and Test on Simulated Data

Run on Real Vehicle

Significantly cut down on development time (**6~12 months per sensor**) to bring up new E2E functionality, saving **~200 engineer years** given >10 sensor types used & humongous corner cases' synthetic data generation

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

Data Productivity

Best performing solution to improve entire data processing pipeline efficiency

Sensor Calibration

Static calibration provides ground truth for sensors by estimating nominal parameters

Time Synchronization

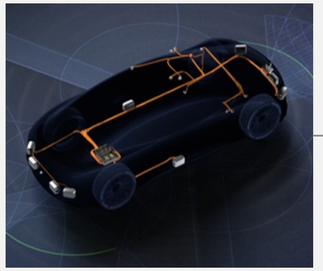
All sensors are timestamped with PTP or TSC domain and aligned to single time source

Data Compression

Lossless compression for safety evaluation and storage usage efficiency

System Management

Dedicated x86 machine to offload visualization and provide console logging

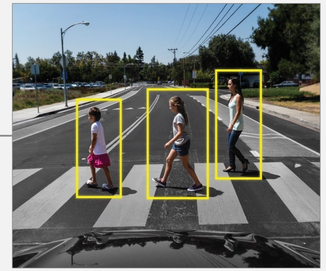


Data Ingestion

Required fleet vehicles and driving miles ↓

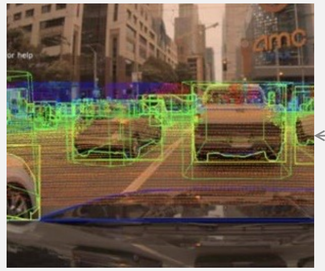
Data Curation

Frames need curation ↓



Data Labeling

Managed labelers and scenes need labeling ↓



Data Validation

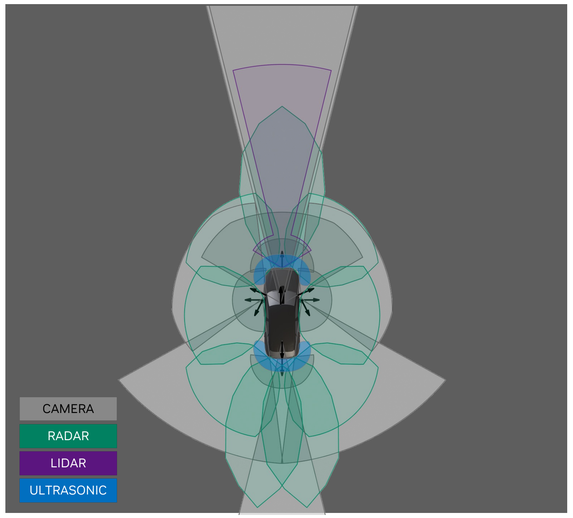
Data need processing ↓

Accelerated AV Development ↑

Saving **~450 engineer years** (150 engineers x 3 years) throughout entire data operation pipeline, from data acquisition to AI models training

Hyperion Accelerates Partner Development

Hyperion architecture alignment saves 1800 engineer years | >$400M of investment

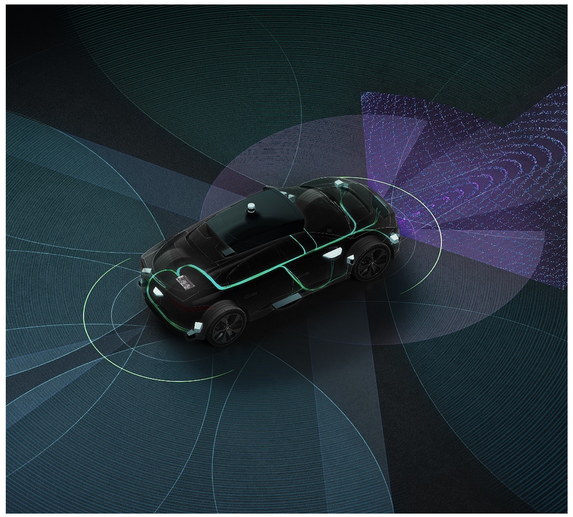


Safety & Security Certified L2+/L3 Multi-sensor AV + IX Architecture

1000 engineering years saved

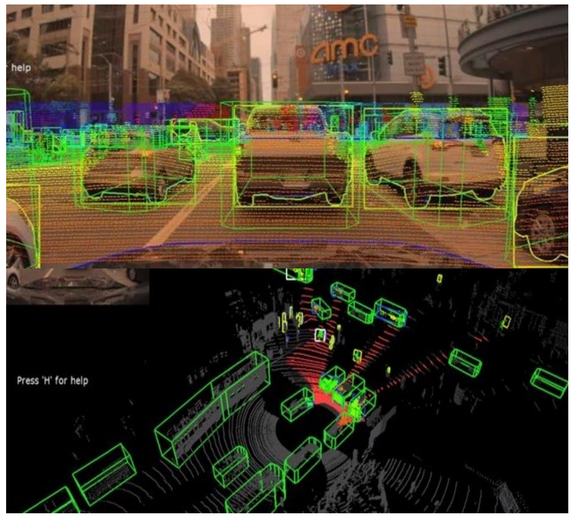
Fully Validated & Tuned Sensor Drivers

150 engineering years saved



Access To Sim Sensor Models & Hyp8 Infra

200 engineering years saved



4D Data Collection For Efficient E2E Development

450 engineering years saved

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DRIVE Camera Engagement Options

Program	References	Custom Lens	Production HW	Production SW	Validation
Hyperion 8.1*	Modules, drivers, tuning, sim models NVIDIA	N/A	Valeo	Drivers, tuning, sim models, safety & security primitives NVIDIA	NVIDIA / OEM
Ecosystem Cameras	Reference Cameras	Open	NVIDIA Design Guide**	AVL / SOW***	OEM

* AS-IS: Customer accepts all production software as-is, any customizations move into “Ecosystem Cameras” engagement flow

** Design Guide: Hardware vendor is up to customer, but vendor must follow Nvidia design guide and ensure compatibility

*** AVL / SOW: Production camera projects require significant training, approved vendors with project specific statement of work

Supported Components: https://developer.nvidia.com/drive/ecosystem-hw-sw

Responsibility

NVIDIA	3rd Party	Compatibility Restriction

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

DRIVE Camera Tuning Support Flow

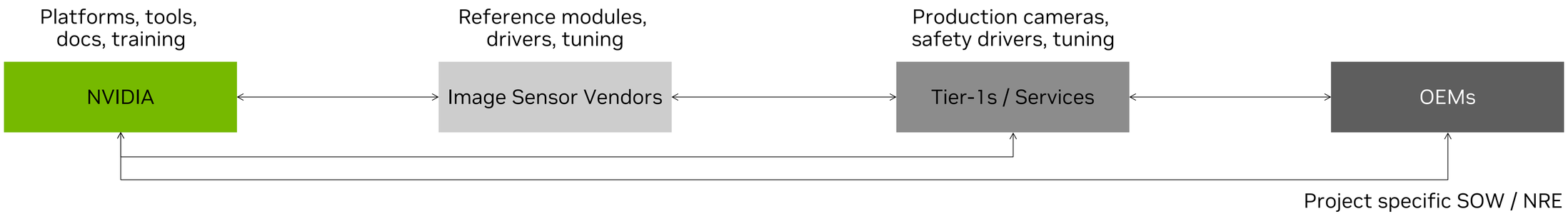


Image Sensor Vendors:

Sony:	IMX390, IMX490, IMX424, IMX623*, IMX728*
ON Semi:	AR0233, AR0820, AR0825, AR0234
OmniVision:	OX08A, OX08B, OX03C, OX03F, OV2311*, OX05B1S*

Tier-1s / Services:

IS Vendors:	Sony*, ON Semi, OmniVision
Tier-1s:	Valeo*, ZF, Desay, Quanta Computer
Services:	ThunderSoft, Cogent, IAV, ArcherMind

*Hyperion 8.1 DevKit

Leveraging Hyperion 8.1 Platform Provides:

- Fastest and most economical approach for mass production
- Accelerating AV & In-cabin algorithms development
- Production sensors / components suite & DRIVE SDK
- Fully integrated, synchronized, validated sensors for 4D data collection & L2+ / L3 driving & L4 parking
- Seamless support from DRIVE Sim includes raytracing-based sensor models to enable full sensor simulation in SIL
  - Preset, configure, custom sensor modules to meet specific requirements
  - Physically accurate sensor simulation in real-time
  - Time-stamped world model & per-ray timestamps

NVIDIA CONFIDENTIAL. DO NOT DISTRIBUTE.

NVIDIA