



AVSIMULATION

AV systems validation using SCANeR studio software

Alex Grandjean – AV Validation project leader

AVSIMULATION PRESENTATION

30 YEARS EXPERIENCE IN SIMULATION, AUTOMOTIVE AND ENGINEERING



SCANeR™

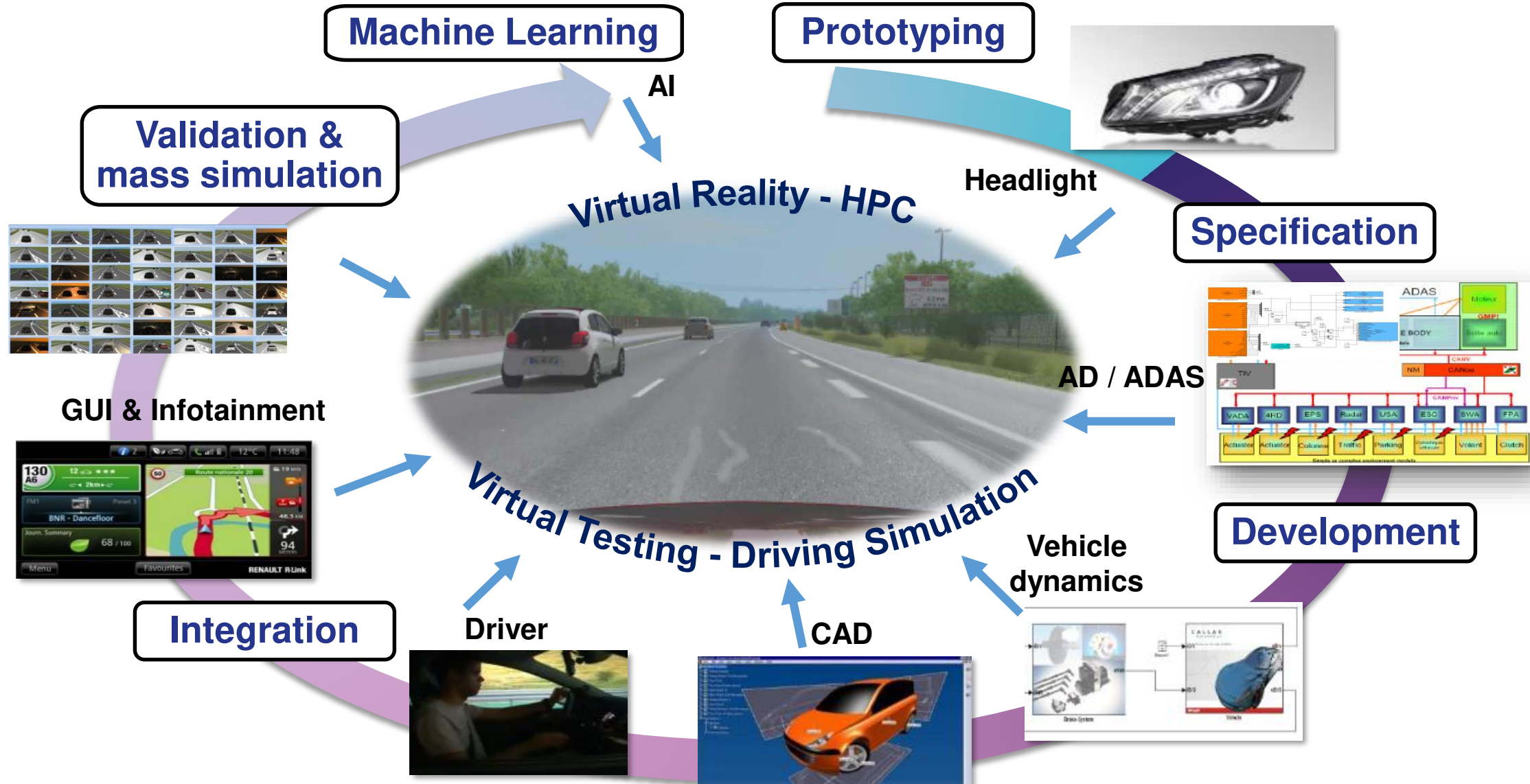
Creation date : 2017
2018 Turnover: 12,5 M €
Employees: 90

Area of expertise:

- Automotive
- Driving simulation
- Autonomous Driving
- Software development




SCANeR™ ACROSS THE INNOVATION LIFECYCLE



WHY SIMULATION FOR AV VALIDATION ?

Billions of Miles Of Testing?

- **Need to test for at least ~3x crash rate to validate safety**
 - Hypothetical deployment: NYC Medallion Taxi Fleet
 - 13,437 vehicles @ 70,000 miles/yr = 941M miles/year
 - 7 critical crashes in 2015 [2014 NYC Taxi Fact Book]
[Fatal and Critical Injury data / Local Law 31 of 2014]
134M miles/critical crash (death or serious injury)
- **How much testing to validate critical crash rate?**
 - Answer: 3x – ~10x the mean crash rate
 - 3x is without any crash
 - If you get a crash, you need to test longer
 - Design changes reset the testing clock
- **Assumes random independent arrivals**
 - Exponential inter-arrival spacing
 - *Is this a good assumption?*




Testing Miles	Confidence if NO critical crash seen
122.8M	60%
308.5M	90%
401.4M	95%
617.1M	99%


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Is Trillions of Miles of Testing Enough?

- **At best, each road hazard type arrives independently**
 - But, that doesn't tell us how often each event arrives
 - No surprise if distribution of scenarios is heavy-tailed
 - E.g., exponential arrivals, but power law distribution of scenarios
- **Beyond that, conditions are not random/independent**
 - Correlations: geographic region, weather, holiday, commute
 - Betting against a heavy tail edge case distribution is risky
- **Need to think more deeply than "drive a lot of miles"**
 - Need to have some assurance your system will work beyond accumulating miles
 - That's what software safety approaches are for!
 - OK, so what happens if you try to apply ISO 26262? ...



Haleakalā National Park



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WHY SIMULATION FOR AV VALIDATION ?

Validating High-ASIL Systems via Testing Is Challenging

Need to test for at least ~3x crash rate to validate safety

- Hypothetical fleet deployment: New York Medallion Taxi Fleet
 - 13,437 vehicles, average 70,000 miles/yr = 941M miles/year
 - 7 critical crashes in 2015 [2014 NYC Taxi Fact Book]
[Fatal and Critical Injury data / Local Law 31 of 2014]
 - 134M miles/critical crash (death or serious injury)

- Assume testing representative; faults are random independent
 - $R(t) = e^{-\lambda t}$ is the probability of not seeing a crash during testing

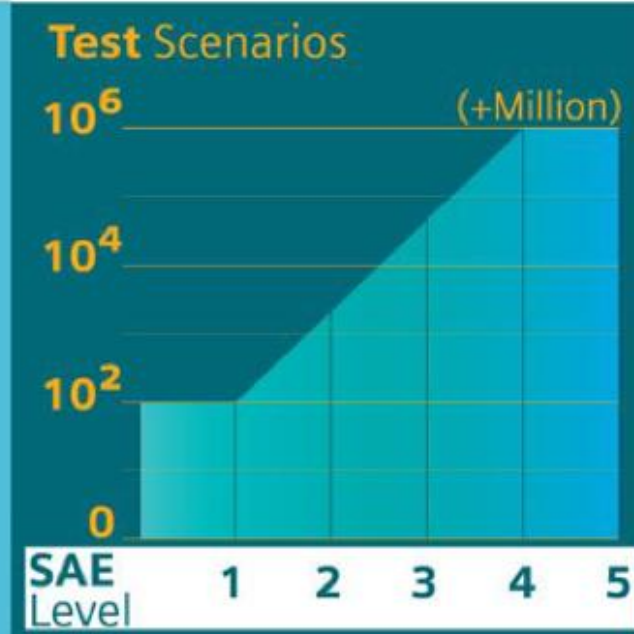
- Illustrative: How much testing to ensure critical crash rate is at least as good as human drivers? → (At least 3x crash rate)
 - These are optimistic test lengths...
 - Assumes random independent arrivals
 - Is simulated driving accurate enough?

Testing Miles	Confidence if NO critical crash seen
122.8M	60%
308.5M	90%
401.4M	95%
617.1M	99%

Using chi-square test from: http://reliabilityanalyticstoolkit.appspot.com/mtbf_test_calculator

WHY SIMULATION FOR AV VALIDATION ?

- The number of scenarios to validate controls will explode from SAE automation level 1 to level 5. Physical testing only is no longer feasible.
- "14.2 billion miles of testing is needed"
Akio Toyoda, CEO of Toyota
Paris Auto Show 2016



2 Million miles

over 12 months

2.7 Billion miles

in our virtual world

WAYMO
2017



WHY SIMULATION FOR AV VALIDATION ?

2 Million miles

over 12 months

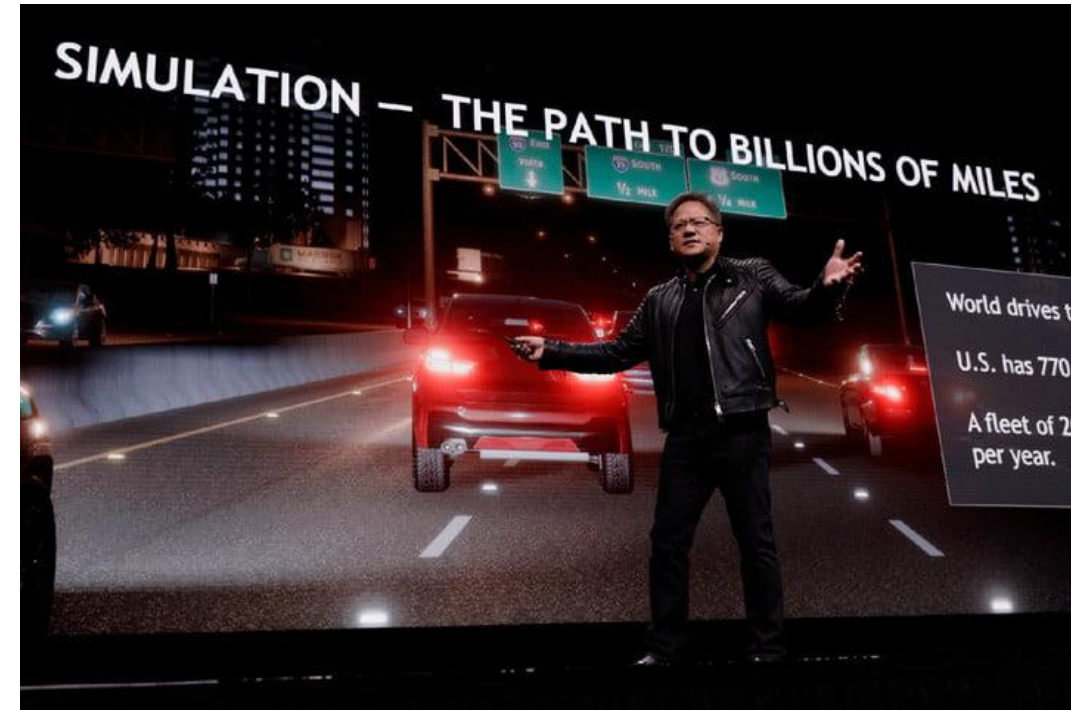
2.7 Billion miles

in our virtual world



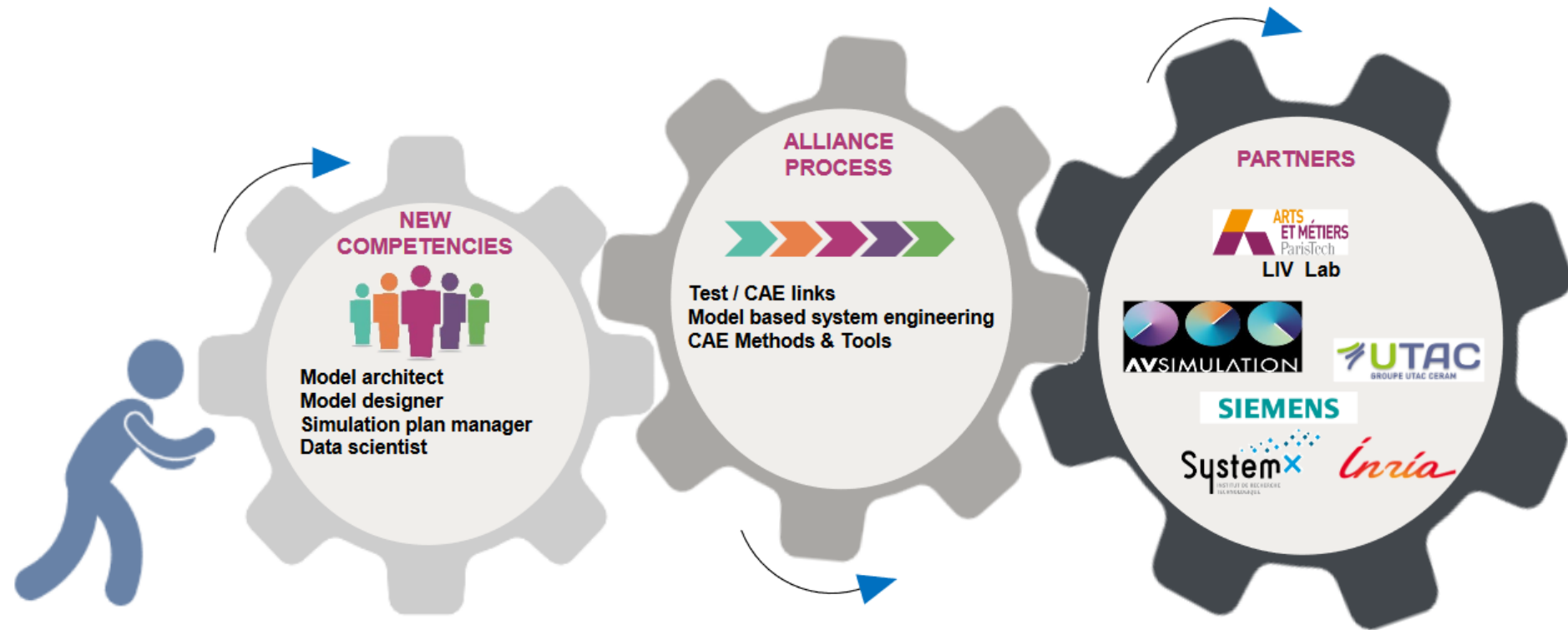
WAYMO

2017



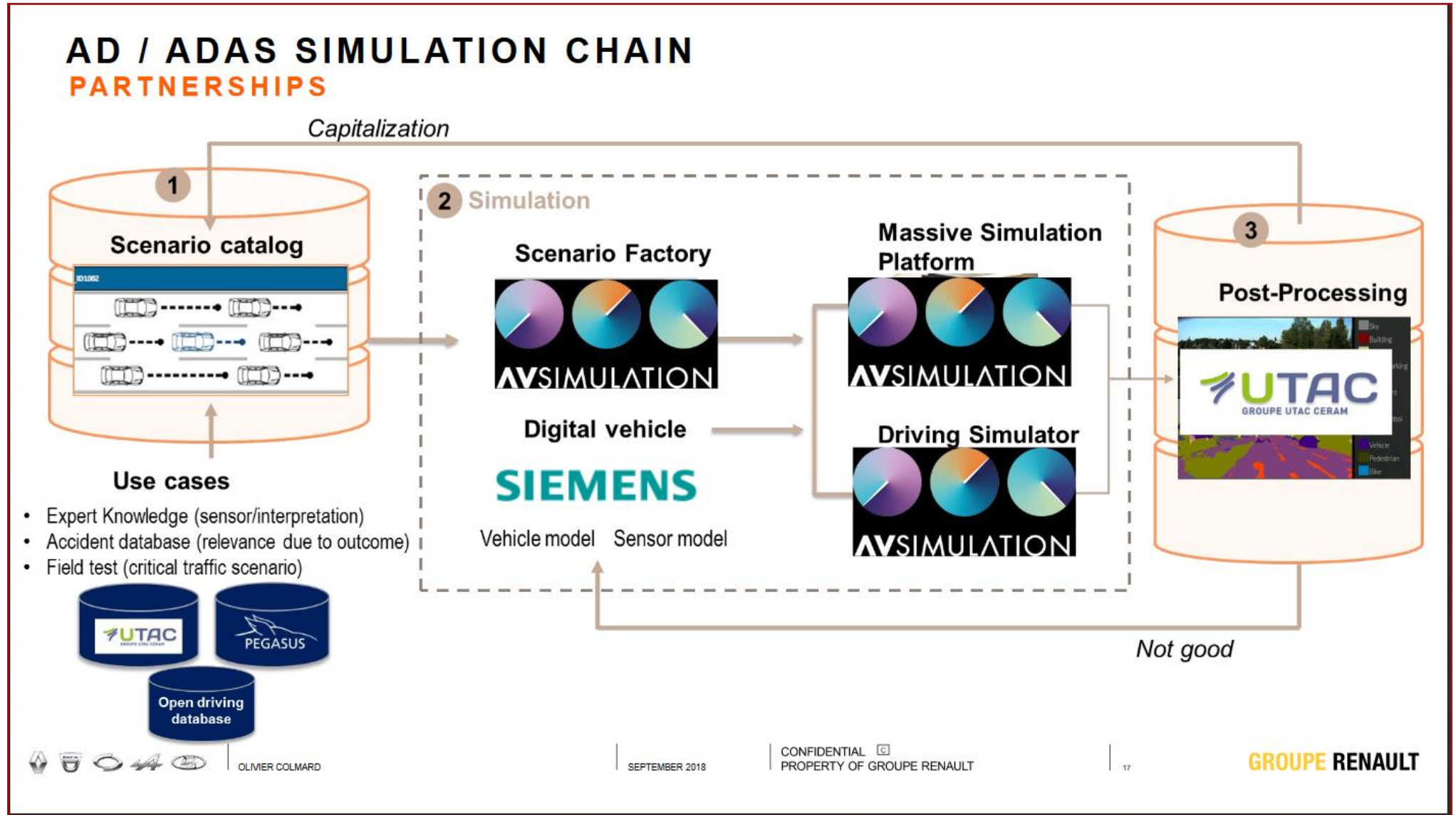
WHY SIMULATION FOR AV VALIDATION ?

AD SIMULATION ECO-SYSTEM



Simulation and Driving simulator are key to develop and validate new connected and autonomous vehicles

WE ARE THE BACKBONE OF RENAULT AD SIMULATION

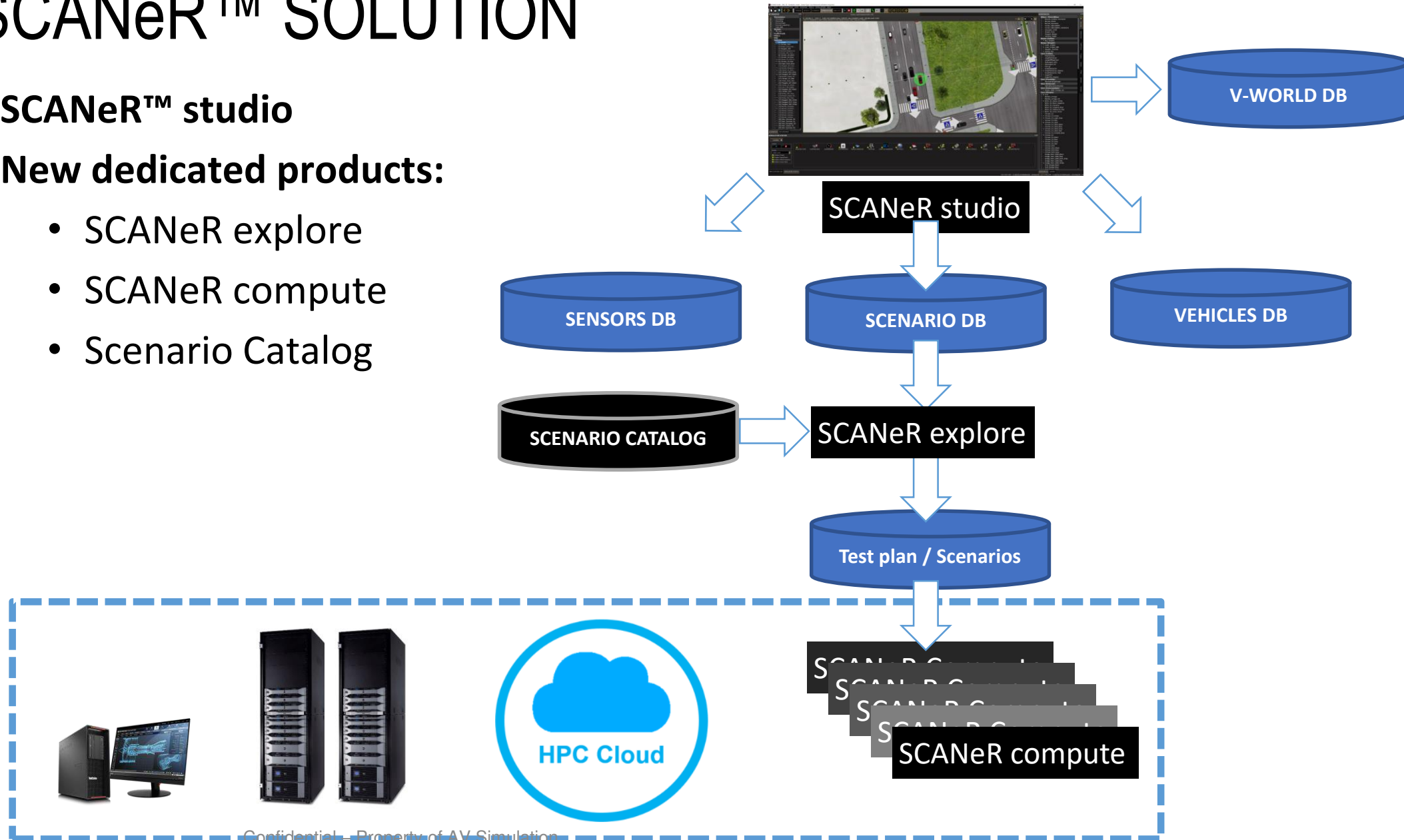


AV VALIDATION CHALLENGES

- **Representative models for the virtual world, sensors, vehicles**
- **Scenario creation & generation**
- **Massive parallel execution**
- **Metrics computation**

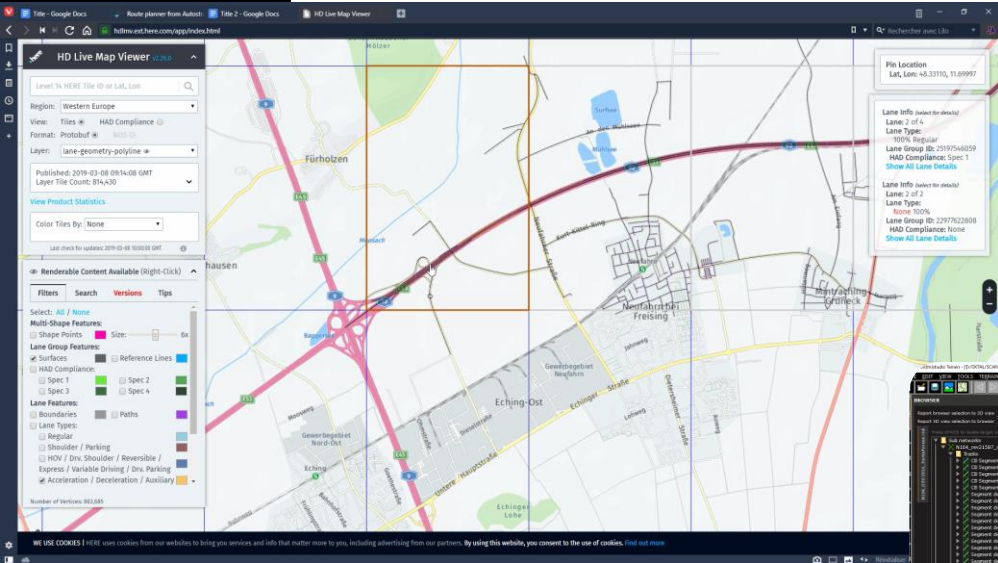
SCANeR™ SOLUTION

- SCANeR™ studio
- New dedicated products:
 - SCANeR explore
 - SCANeR compute
 - Scenario Catalog

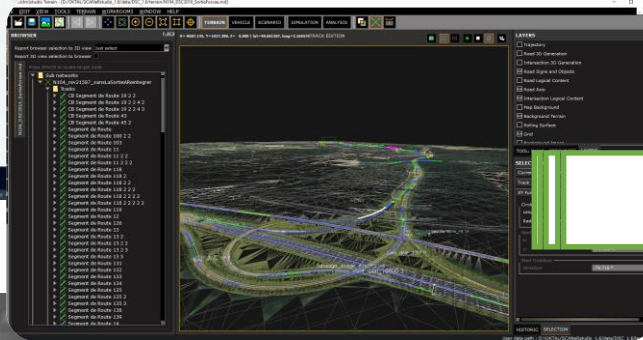


Representative models for the Virtual world, sensors, vehicles

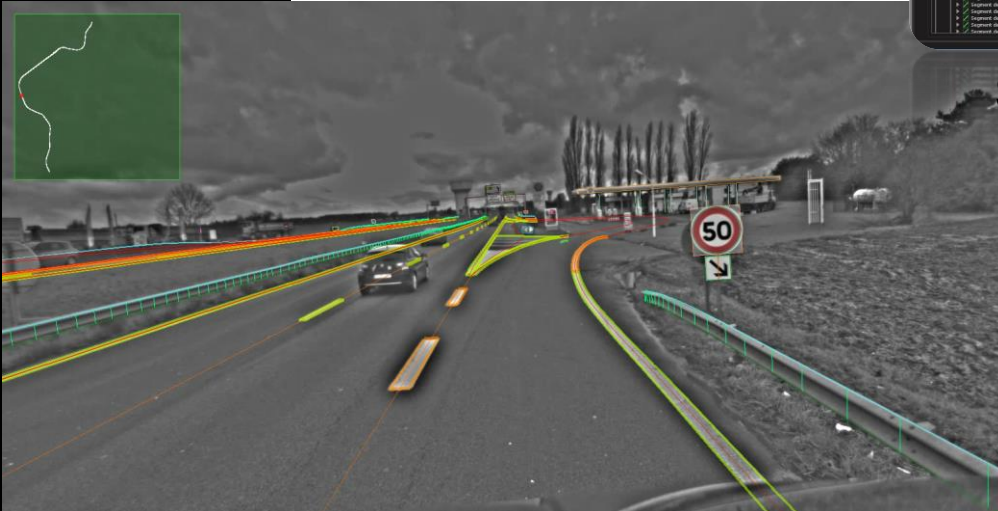
BUILD A DIGITAL WORLD



HD Maps

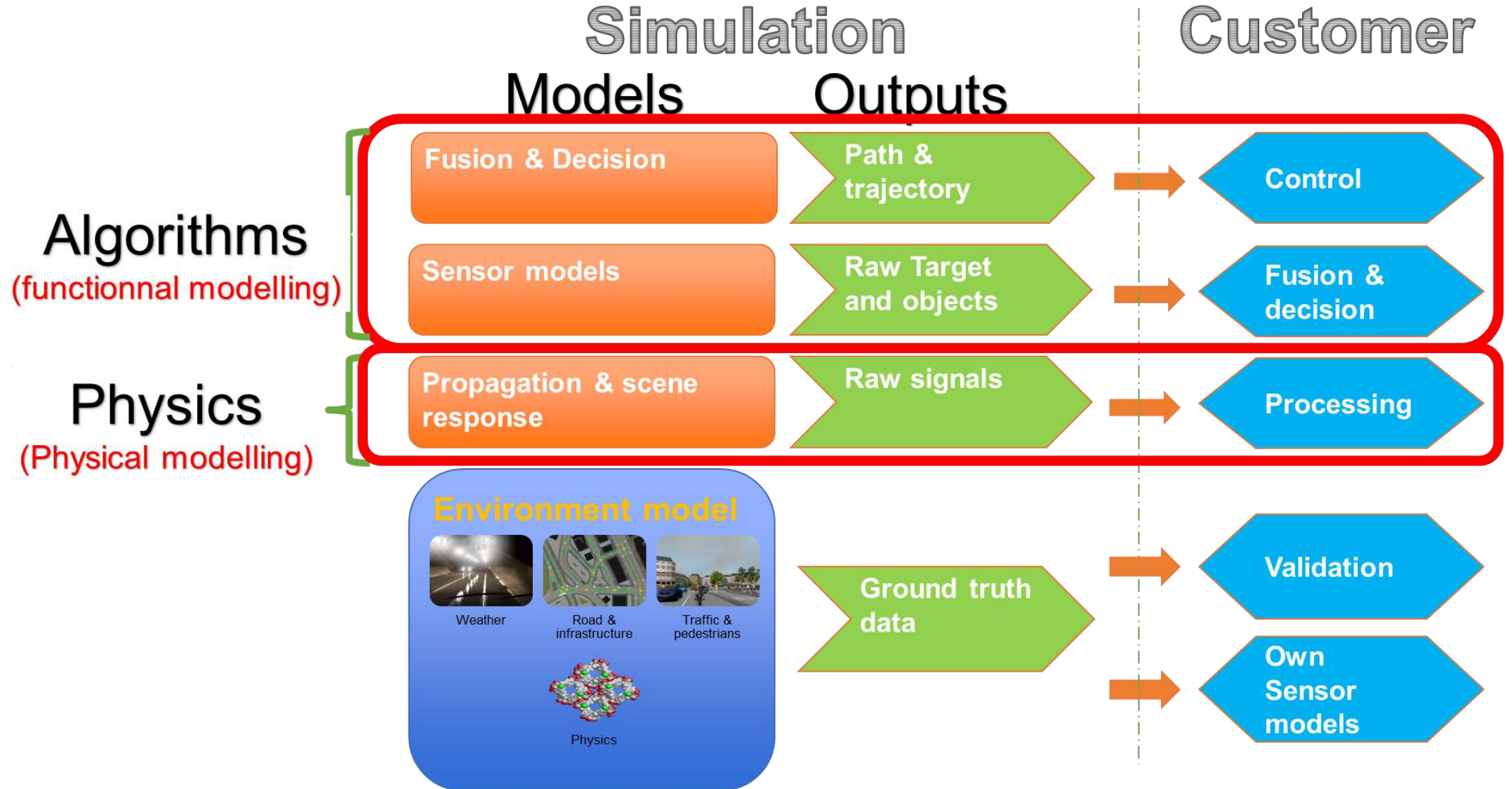


SCANeR™ studio : Terrain



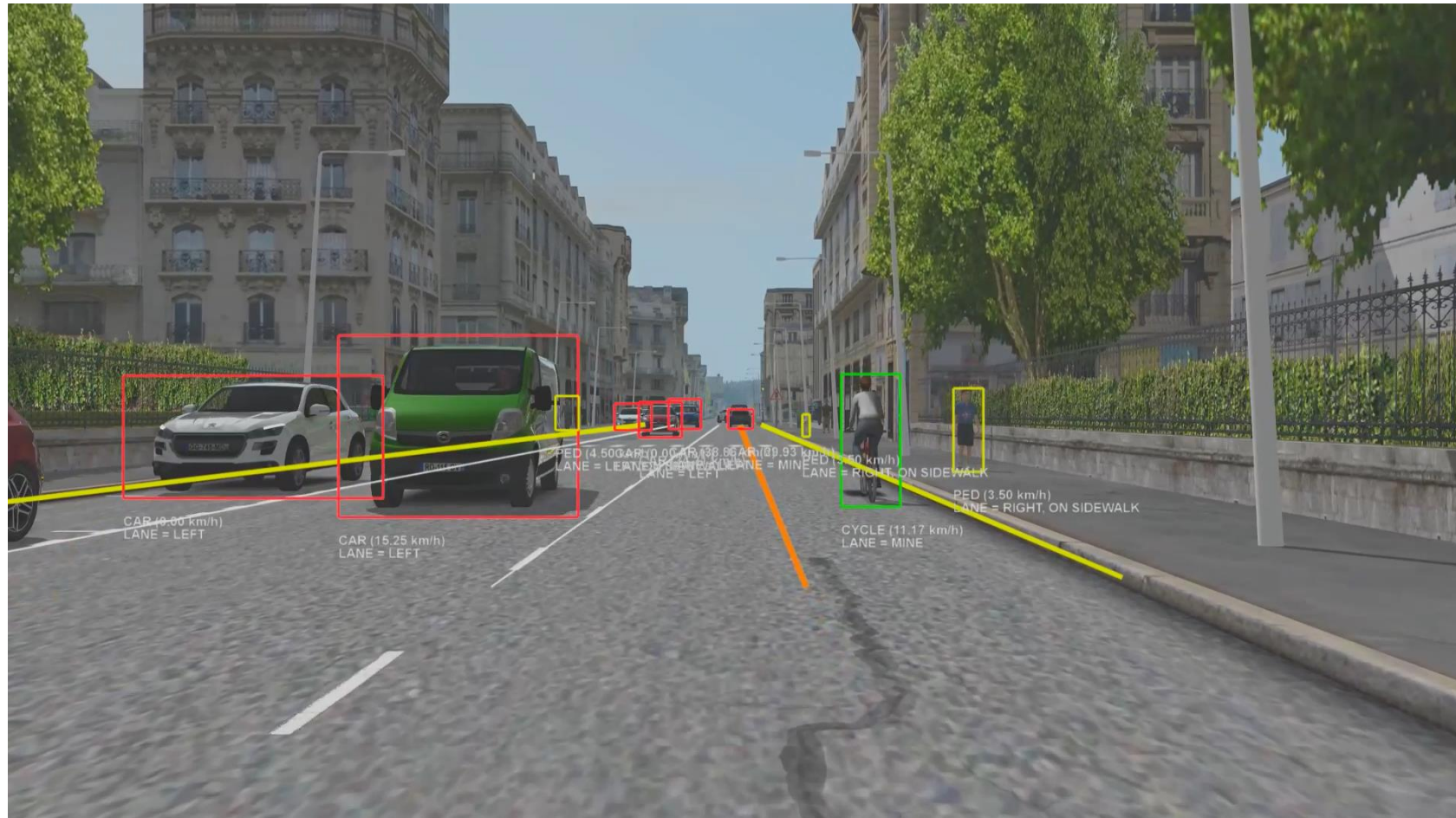
Acquisitions

STRATEGIES FOR SENSOR MODELLING



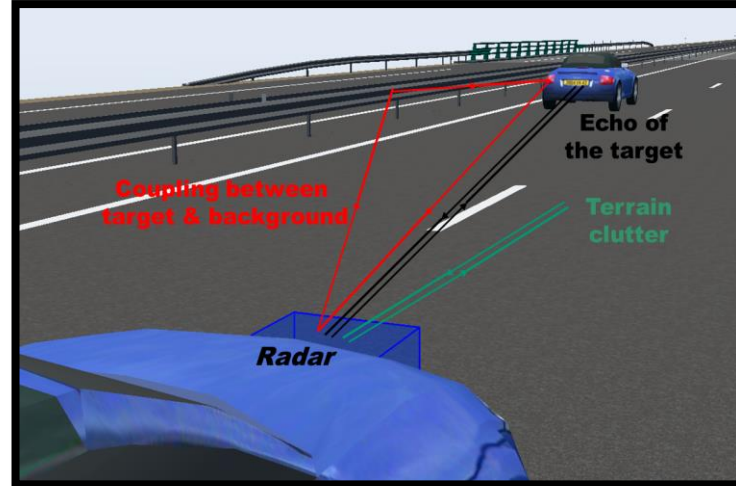
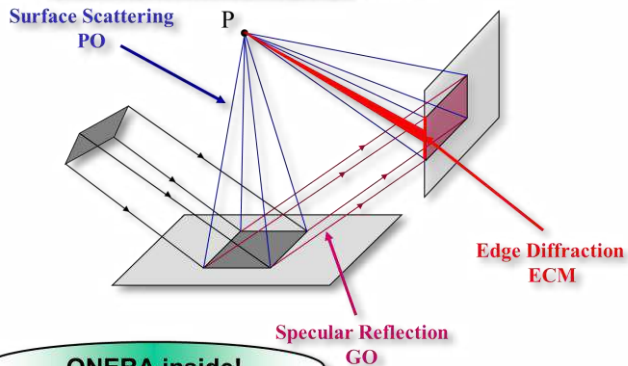
FUNCTIONNAL MODELLING

- Simulate the algorithms!

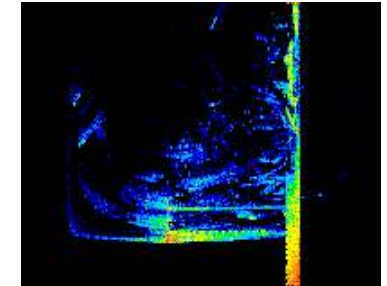
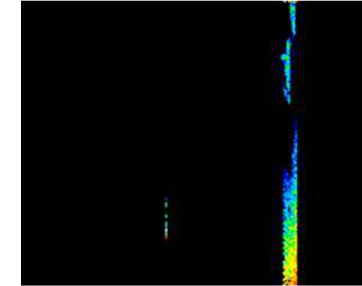


RADAR SIMULATION AT PHYSICAL LEVEL

Asymptotic formulations of Maxwell's equations combined with shooting and bouncing rays (SBR)

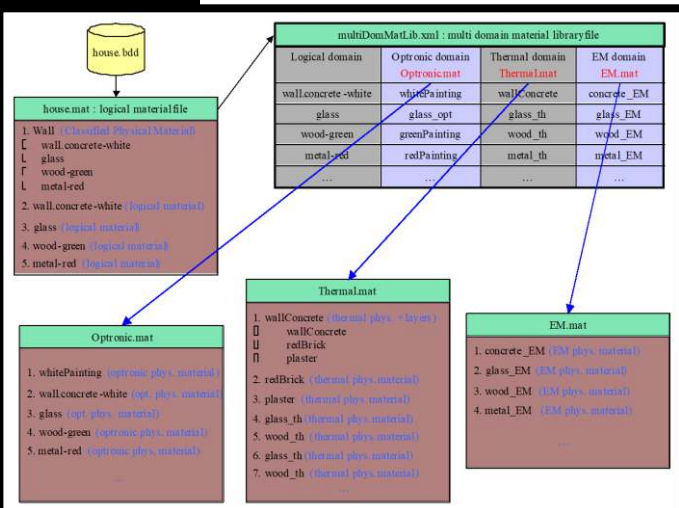
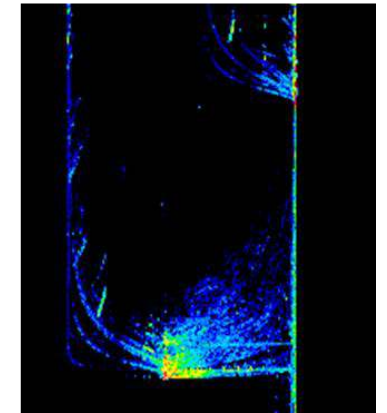
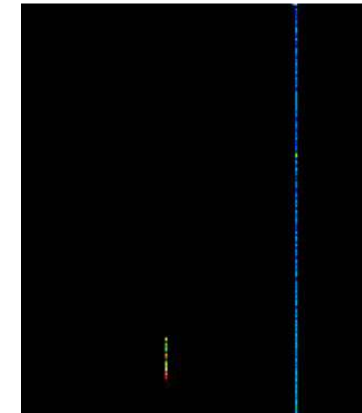


Doppler maps

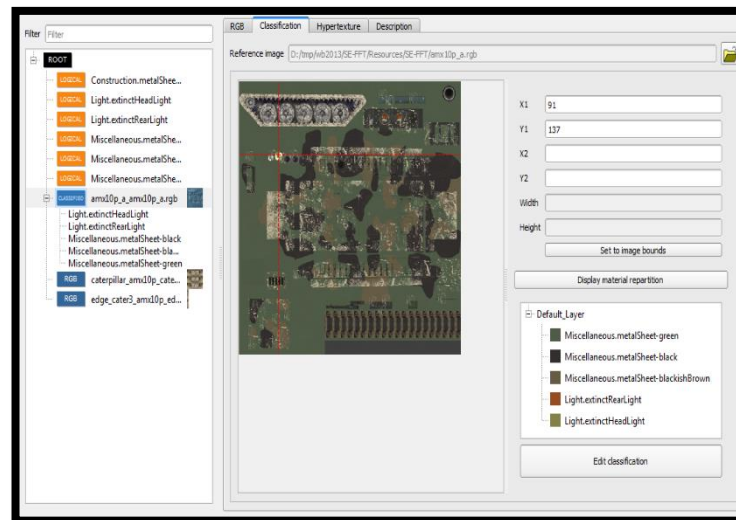


No coupling

coupling



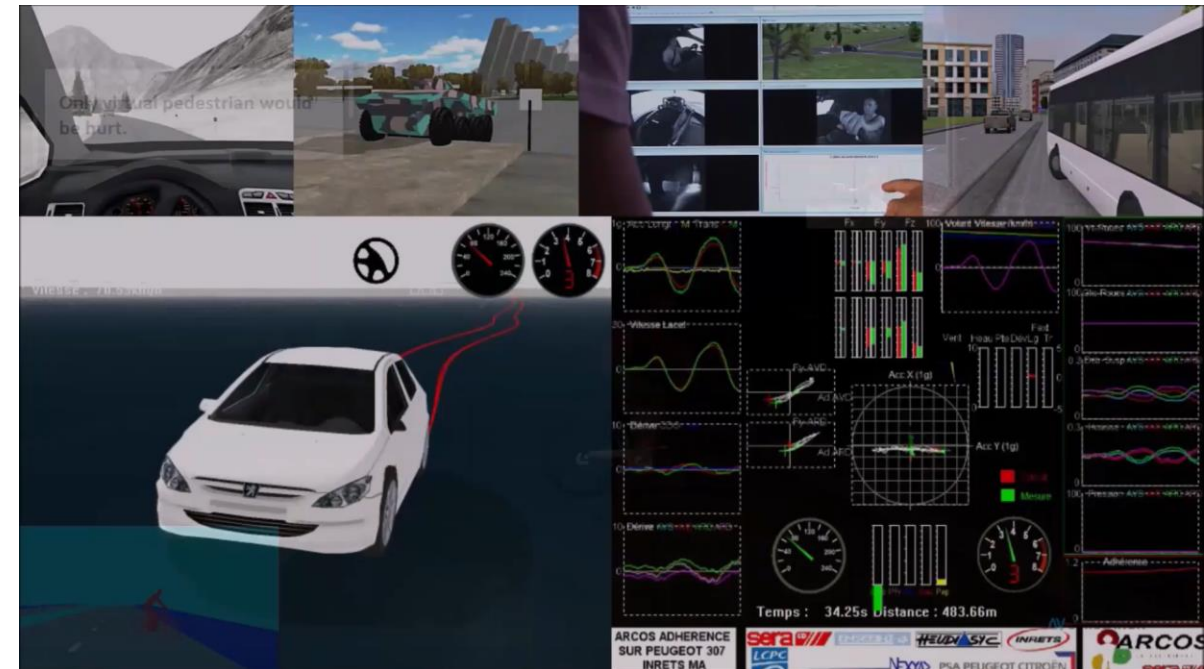
Material database



Object classification

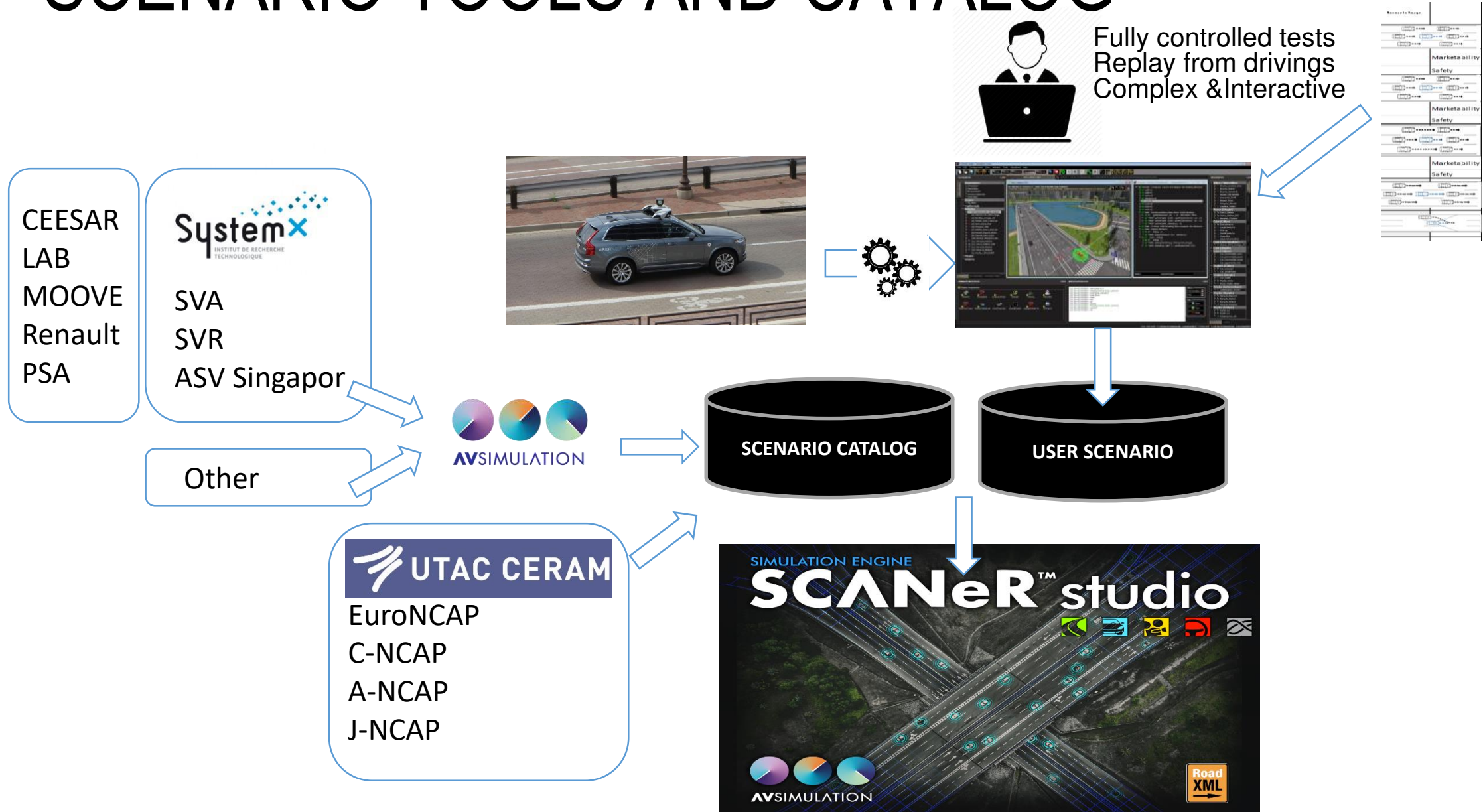
MODELLING THE VEHICLE

- **SCANeR includes CALLAS model**
 - Validated in a large scope of applications
 - C/C++ & Simulink API + FMI to create external Sub-models
- **Generic interface for Dynamic vehicle models**
 - Custom Simulink model
 - C/C++ API
 - Many models of the market
- **Custom Input/Output to exchange internal data with distributed simulation**
- **FMI support**



Scenario creation

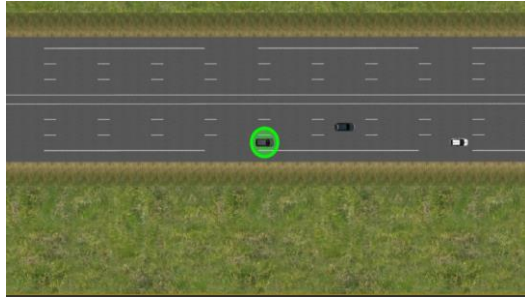
SCENARIO TOOLS AND CATALOG



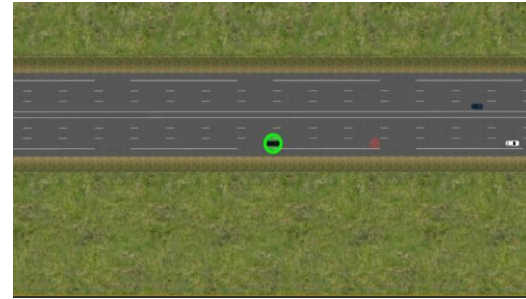
KEY ASPECTS FOR SCENARIO MODELING

- **20 years of expertise of complex interactive scenario**
- **Models**
 - Environment (Infrastructure, Roads, Weather)
 - Traffic (Flows, Densities, Types)
 - Vehicle dynamics
 - Drivers (Real, Trajectory, Commands)
 - Maneuvers (Lane following, Lane change, curves)
 - Systems (ADAS, HMI)
- **Scripting**
 - Intensive function library to interact with models
 - *Interrogate*
 - *Take control*
 - Powerful scripting tools

SCENARIO CATALOG PREVIEW



Simultaneous maneuvers



Cut-in



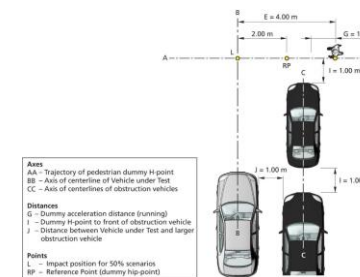
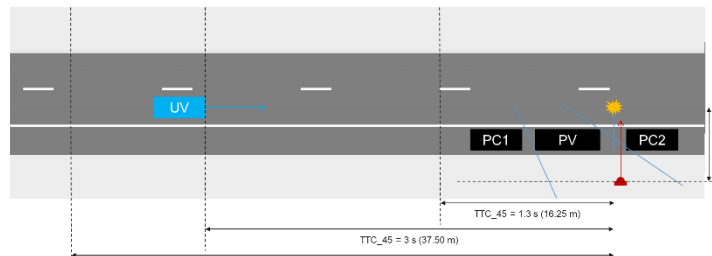
Cut Through



CCRB

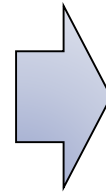
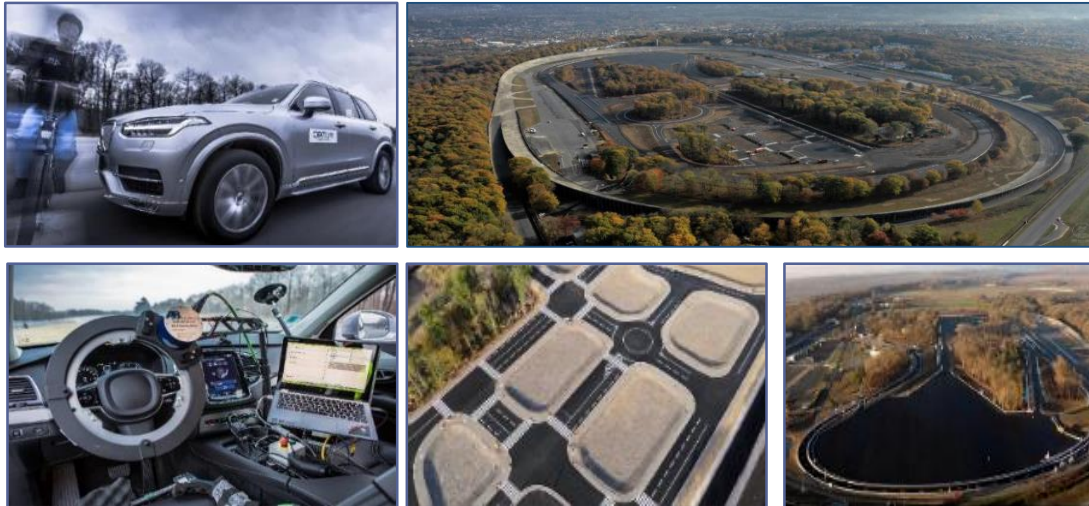


CPNC-50 AEB pedestrian



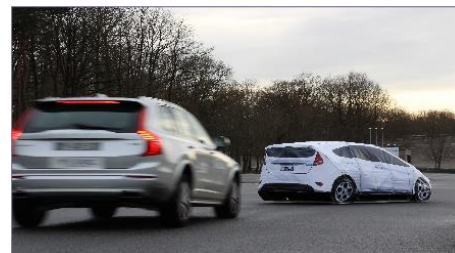
UTAC CERAM COLLABORATION

- UTAC CERAM, french laboratory, EuroNCAP accredited
- Physical UTAC CERAM testing expertise implemented into virtual scenarios
- Correlation between real and virtual test



- Official NCAP scenarios (EuroNCAP, ANCAP...)

Car to car scenarios



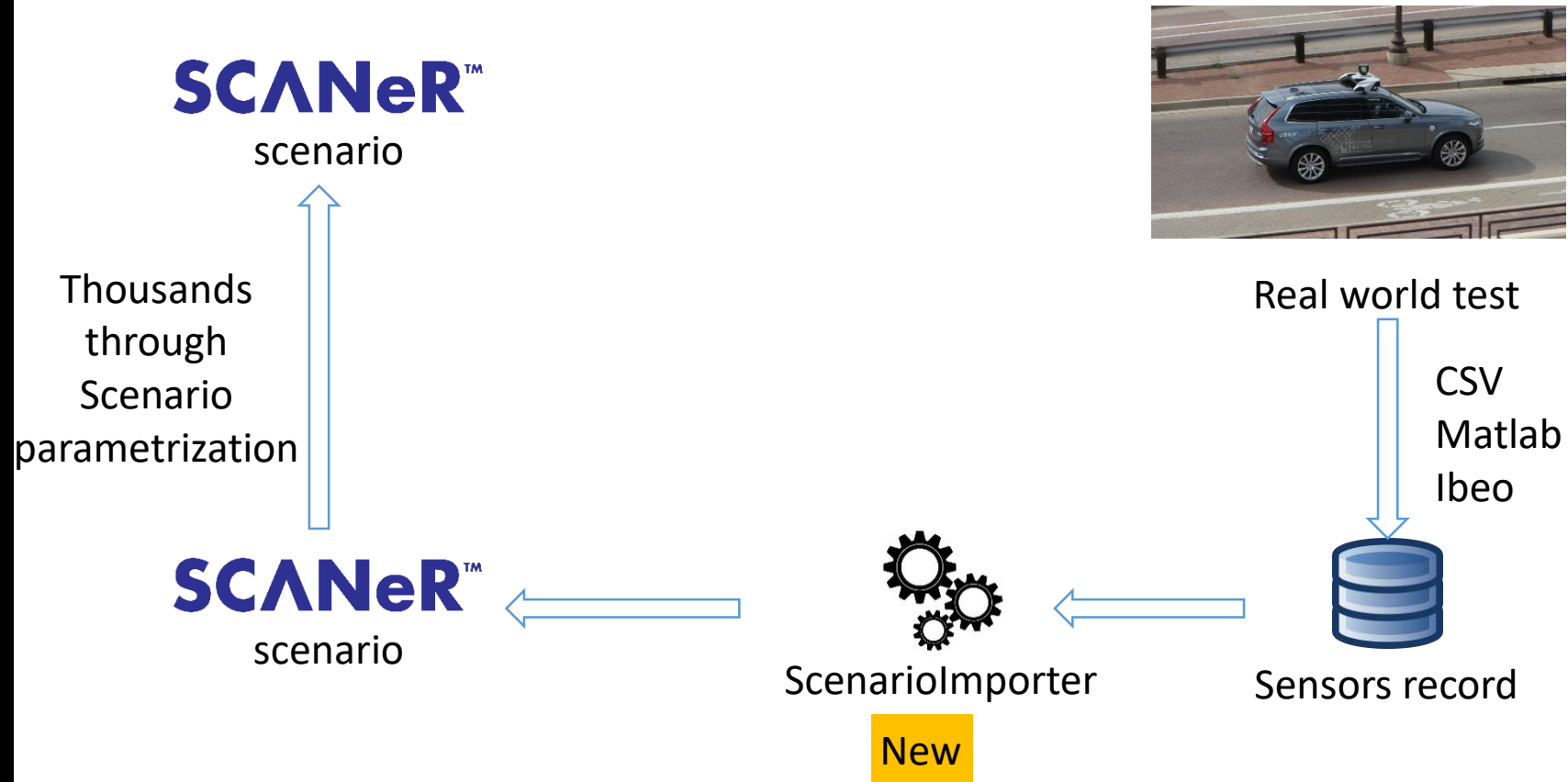
Bicycle scenarios



Pedestrian scenarios



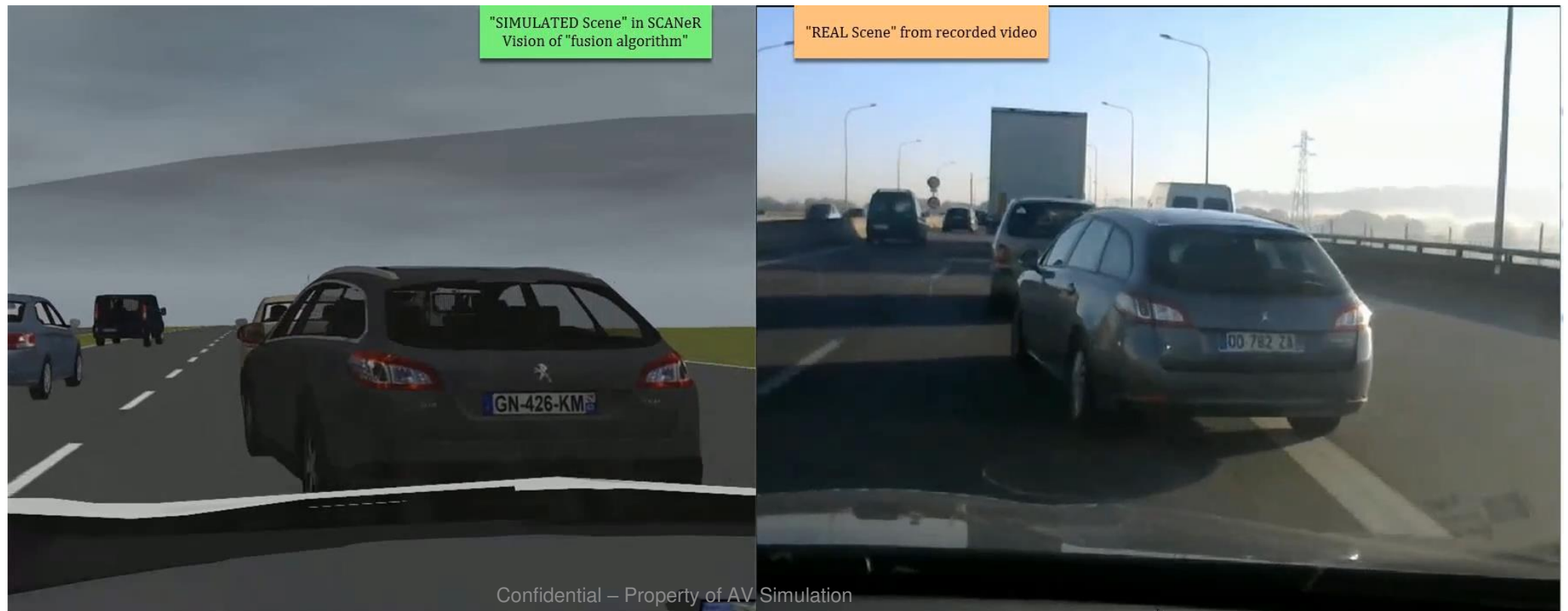
SCENARIO: IMPORT REAL DATA



SCENARIO: IMPORT REAL DATA

- **Very sensitive to the data quality**
 - Ego position must be accurate
 - bad detection → bad scenario.
- **Vehicle position and road position matching**

Courtesy of Renault



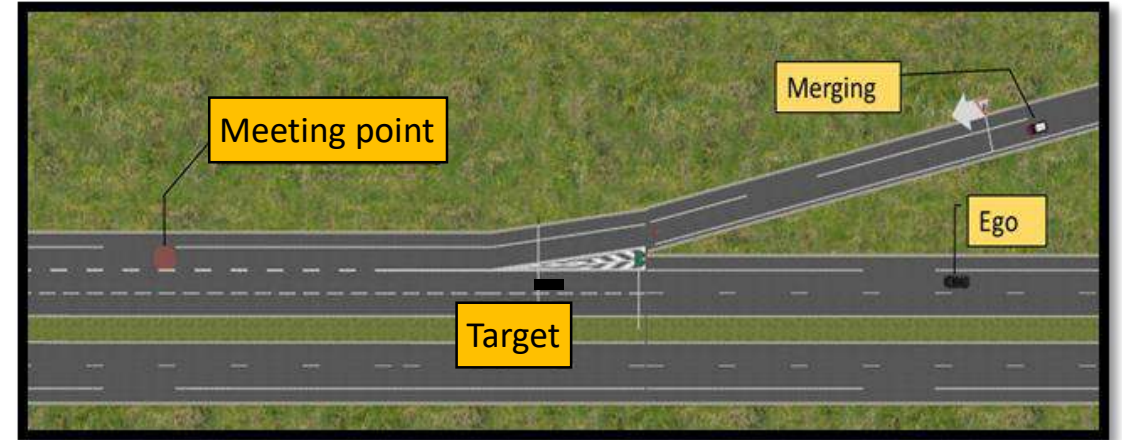
Scenario generation

MOTIVATION

- **Parameters:**

- Ego speed
- Merging vehicle acceleration
- Gap at meeting point
- Delta speed at meeting point
- Merging vehicle lane change duration
- Gap with target
- Meeting point abscissa
- Merge lane length
- Slope
- Curvature
- Time of day
- Weather conditions

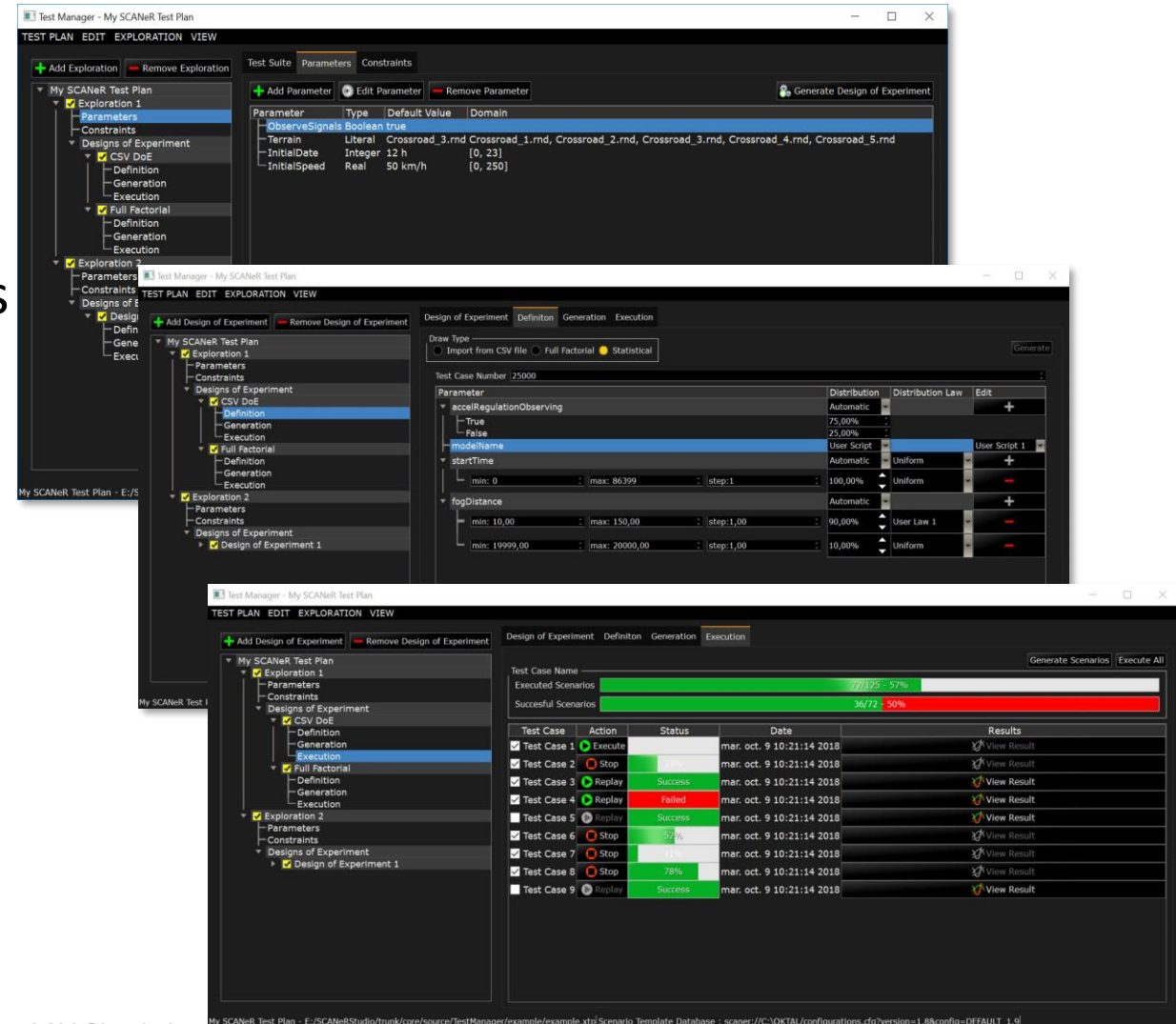
- **5 variations for each → almost 5M scenarios**



Merging scenario

SCANeR explore

- **Test plan editor**
 - Statistical distribution laws
 - Parameters constraints
 - Support all scenario parameters
 - Customizable with python
- **Scenario generator**
- **SCANeR Compute launcher**
- **Job monitoring**
- **Results analysis**



SCANeR explore

- Create test plans & exploration based on scenarios

Test Manager - New Test Plan

TEST PLAN EDIT EXPLORATION GENERATION VIEW

+ Add Exploration - Remove Exploration

- New Test Plan
 - MyExploration
 - Parameters
 - Constraints
 - Designs of Experiment
 - Design of Experiment 1
 - Definition
 - Generation
 - Execution
 - User Script

Test Suite Parameters Constraints User Scripts

Name MyExploration

Scenario Template `${STUDIO_PATH}/SCANeRstudio_1.9/data/DEFAULT/scenario/Studio_3DObjects.sce`

Scenario `${STUDIO_PATH}/SCANeRstudio_1.9/data/DEFAULT/scenario/Studio_3DObjects.sce`

Description

Enabled

SCANeR explore: SCENARIO GENERATION

Test Manager - New Test Plan

TEST PLAN EDIT EXPLORATION GENERATION VIEW

+ Add Design of Experiment - Remove Design of Experiment

Design of Experiment Definiton **Generation** Execution

Export Design of Experiment

Scenario Generation

Add Date Suffix

Custom Prefix

Custom Output Directory

Test Case	Scenario	Action	Date	rainLevel	cloudsLevel	initialSpeed	modelName
Test Case 1	Generate	Folder		0	0.2	0 km/h	Citroen_C3_Green
Test Case 2	Generate	Folder		0	1	0 km/h	Citroen_C3_Green
Test Case 3	Generate	Folder		0	0.2	10 km/h	Citroen_C3_Green
Test Case 4	Generate	Folder		0	1	10 km/h	Citroen_C3_Green
Test Case 5	Generate	Folder		0	0.2	20 km/h	Citroen_C3_Green
Test Case 6	Generate	Folder		0	1	20 km/h	Citroen_C3_Green
Test Case 7	Generate	Folder		0	0.2	30 km/h	Citroen_C3_Green
Test Case 8	Generate	Folder		0	1	30 km/h	Citroen_C3_Green
Test Case 9	Generate	Folder		0	0.2	40 km/h	Citroen_C3_Green
Test Case 10	Generate	Folder		0	1	40 km/h	Citroen_C3_Green
Test Case 11	Generate	Folder		0	0.2	50 km/h	Citroen_C3_Green
Test Case 12	Generate	Folder		0	1	50 km/h	Citroen_C3_Green
Test Case 13	Generate	Folder		0	0.2	60 km/h	Citroen_C3_Green
Test Case 14	Generate	Folder		0	1	60 km/h	Citroen_C3_Green
Test Case 15	Generate	Folder		0	0.2	70 km/h	Citroen_C3_Green

No task are currently running

01.sce	040.sce	079.sce	0118.sce	0157.sce	0196.sce	0235.sce	0274.sce	0313.sce	0352.sce	0391.sce
02.sce	041.sce	080.sce	0119.sce	0158.sce	0197.sce	0236.sce	0275.sce	0314.sce	0353.sce	0392.sce
03.sce	042.sce	081.sce	0120.sce	0159.sce	0198.sce	0237.sce	0276.sce	0315.sce	0354.sce	0393.sce
04.sce	043.sce	082.sce	0121.sce	0160.sce	0199.sce	0238.sce	0277.sce	0316.sce	0355.sce	0394.sce
05.sce	044.sce	083.sce	0122.sce	0161.sce	0200.sce	0239.sce	0278.sce	0317.sce	0356.sce	0395.sce
06.sce	045.sce	084.sce	0123.sce	0162.sce	0201.sce	0240.sce	0279.sce	0318.sce	0357.sce	0396.sce
07.sce	046.sce	085.sce	0124.sce	0163.sce	0202.sce	0241.sce	0280.sce	0319.sce	0358.sce	0397.sce
08.sce	047.sce	086.sce	0125.sce	0164.sce	0203.sce	0242.sce	0281.sce	0320.sce	0359.sce	0398.sce
09.sce	048.sce	087.sce	0126.sce	0165.sce	0204.sce	0243.sce	0282.sce	0321.sce	0360.sce	0399.sce
010.sce	049.sce	088.sce	0127.sce	0166.sce	0205.sce	0244.sce	0283.sce	0322.sce	0361.sce	0400.sce
011.sce	050.sce	089.sce	0128.sce	0167.sce	0206.sce	0245.sce	0284.sce	0323.sce	0362.sce	0401.sce
012.sce	051.sce	090.sce	0129.sce	0168.sce	0207.sce	0246.sce	0285.sce	0324.sce	0363.sce	0402.sce
013.sce	052.sce	091.sce	0130.sce	0169.sce	0208.sce	0247.sce	0286.sce	0325.sce	0364.sce	0403.sce
014.sce	053.sce	092.sce	0131.sce	0170.sce	0209.sce	0248.sce	0287.sce	0326.sce	0365.sce	0404.sce
015.sce	054.sce	093.sce	0132.sce	0171.sce	0210.sce	0249.sce	0288.sce	0327.sce	0366.sce	0405.sce
016.sce	055.sce	094.sce	0133.sce	0172.sce	0211.sce	0250.sce	0289.sce	0328.sce	0367.sce	0406.sce
017.sce	056.sce	095.sce	0134.sce	0173.sce	0212.sce	0251.sce	0290.sce	0329.sce	0368.sce	0407.sce
018.sce	057.sce	096.sce	0135.sce	0174.sce	0213.sce	0252.sce	0291.sce	0330.sce	0369.sce	0408.sce
019.sce	058.sce	097.sce	0136.sce	0175.sce	0214.sce	0253.sce	0292.sce	0331.sce	0370.sce	0409.sce
020.sce	059.sce	098.sce	0137.sce	0176.sce	0215.sce	0254.sce	0293.sce	0332.sce	0371.sce	0410.sce
021.sce	060.sce	099.sce	0138.sce	0177.sce	0216.sce	0255.sce	0294.sce	0333.sce	0372.sce	0411.sce
022.sce	061.sce	100.sce	0139.sce	0178.sce	0217.sce	0256.sce	0295.sce	0334.sce	0373.sce	0412.sce
023.sce	062.sce	101.sce	0140.sce	0179.sce	0218.sce	0257.sce	0296.sce	0335.sce	0374.sce	0413.sce
024.sce	063.sce	102.sce	0141.sce	0180.sce	0219.sce	0258.sce	0297.sce	0336.sce	0375.sce	0414.sce
025.sce	064.sce	103.sce	0142.sce	0181.sce	0220.sce	0259.sce	0298.sce	0337.sce	0376.sce	0415.sce
026.sce	065.sce	104.sce	0143.sce	0182.sce	0221.sce	0260.sce	0299.sce	0338.sce	0377.sce	0416.sce
027.sce	066.sce	105.sce	0144.sce	0183.sce	0222.sce	0261.sce	0300.sce	0339.sce	0378.sce	0417.sce
028.sce	067.sce	106.sce	0145.sce	0184.sce	0223.sce	0262.sce	0301.sce	0340.sce	0379.sce	0418.sce
029.sce	068.sce	107.sce	0146.sce	0185.sce	0224.sce	0263.sce	0302.sce	0341.sce	0380.sce	0419.sce
030.sce	069.sce	108.sce	0147.sce	0186.sce	0225.sce	0264.sce	0303.sce	0342.sce	0381.sce	0420.sce
031.sce	070.sce	109.sce	0148.sce	0187.sce	0226.sce	0265.sce	0304.sce	0343.sce	0382.sce	0421.sce
032.sce	071.sce	110.sce	0149.sce	0188.sce	0227.sce	0266.sce	0305.sce	0344.sce	0383.sce	0422.sce
033.sce	072.sce	111.sce	0150.sce	0189.sce	0228.sce	0267.sce	0306.sce	0345.sce	0384.sce	0423.sce
034.sce	073.sce	112.sce	0151.sce	0190.sce	0229.sce	0268.sce	0307.sce	0346.sce	0385.sce	0424.sce
035.sce	074.sce	113.sce	0152.sce	0191.sce	0230.sce	0269.sce	0308.sce	0347.sce	0386.sce	0425.sce
036.sce	075.sce	114.sce	0153.sce	0192.sce	0231.sce	0270.sce	0309.sce	0348.sce	0387.sce	0426.sce
037.sce	076.sce	115.sce	0154.sce	0193.sce	0232.sce	0271.sce	0310.sce	0349.sce	0388.sce	0427.sce
038.sce	077.sce	116.sce	0155.sce	0194.sce	0233.sce	0272.sce	0311.sce	0350.sce	0389.sce	0428.sce
039.sce	078.sce	117.sce	0156.sce	0195.sce	0234.sce	0273.sce	0312.sce	0351.sce	0390.sce	0429.sce

SCANeR Explore: SCENARIO EXECUTION & REPORT

The screenshot shows the SCANeR Explore software interface. The 'Generation' tab is active, displaying a table of scenarios. A dialog box titled 'Executing Scenarios' is open, showing 'Executing scenario 'Studio_3DObjects 1''. The table below lists various scenarios with their generation status, dates, and speeds.

Scenario Name	Generation	Date	EgoSpeed	TargetSpeed
Studio_3DObjects 1	Regenerate	19/5/2019-22h10m00s	64.2732 km/h	99.4412
Studio_3DObjects 2	Regenerate	19/5/2019-22h10m00s	101.263 km/h	21.6922
Studio_3DObjects 3	Generate		4.70976 km/h	131.667
Studio_3DObjects 4	Generate		34.383 km/h	133.388
Studio_3DObjects 5	Generate		48.6291 km/h	112.983
Studio_3DObjects 6	Generate		97.9944 km/h	130.099
Studio_3DObjects 7	Generate		31.8584 km/h	85.9856
Studio_3DObjects 8	Generate		80.8917 km/h	7.87413
Studio_3DObjects 9	Generate		33.7881 km/h	138.365
Studio_3DObjects 10	Generate		70.3137 km/h	143.689
Studio_3DObjects 11	Generate		116.2 km/h	
Studio_3DObjects 12	Generate		50.75 km/h	
Studio_3DObjects 13	Generate		25.16 km/h	
Studio_3DObjects 14	Generate		38.96 km/h	
Studio_3DObjects 15	Generate		50.14 km/h	
Studio_3DObjects 16	Generate		109.6 km/h	
Studio_3DObjects 17	Generate		105.142 km/h	114.978
Studio_3DObjects 18	Generate		120.852 km/h	124.968
Studio_3DObjects 19	Generate		110.175 km/h	46.0243
Studio_3DObjects 20	Generate		28.1595 km/h	61.4035
Studio_3DObjects 21	Generate		2.43490 km/h	95.0603
Studio_3DObjects 22	Generate		49.9660 km/h	128.846
Studio_3DObjects 23	Generate		87.5256 km/h	123.223
Studio_3DObjects 24	Generate		49.1109 km/h	61.411
Studio_3DObjects 25	Generate		66.0635 km/h	145.301
Studio_3DObjects 26	Generate		97.8167 km/h	98.7827
Studio_3DObjects 27	Generate		39.6474 km/h	102.289

Scenario : highway_insert 1

Simulation Infos :	
Real duration	0.798723
Real time ratio	37.58
Simulated duration	30
Step done	800

Scenario criteria :	
TEST GREEN	●
TEST YELLOW	●
TEST RED	●
TEST GRAY	●

Scenario output variables :	
Dist_Following	-1.000000
Dist_Inserting	-1.000000
Dist_Preceding	-1.000000

Graphs :

Scenario : highway_insert 2

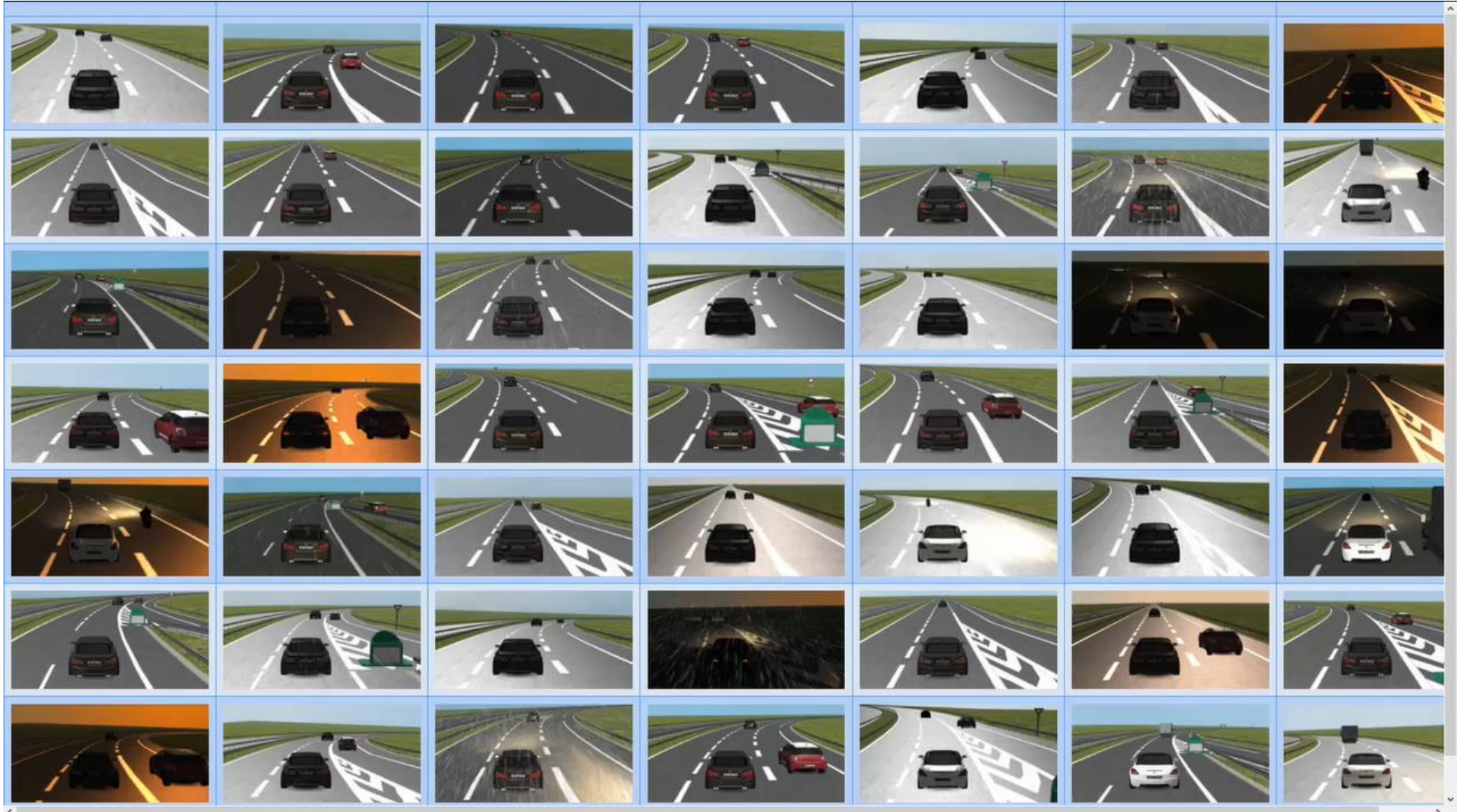
Simulation Infos :	
Real duration	0.821878
Real time ratio	38.5018
Simulated duration	30
Step done	800

Scenario criteria :	
TEST GREEN	● With a very very very lots of criteria info
TEST YELLOW	● With criteria info
TEST RED	● With criteria info
TEST GRAY	● With criteria info

Scenario output variables :	
Dist_Following	-1.000000
Dist_Inserting	-1.000000
Dist_Preceding	-1.000000

Graphs :

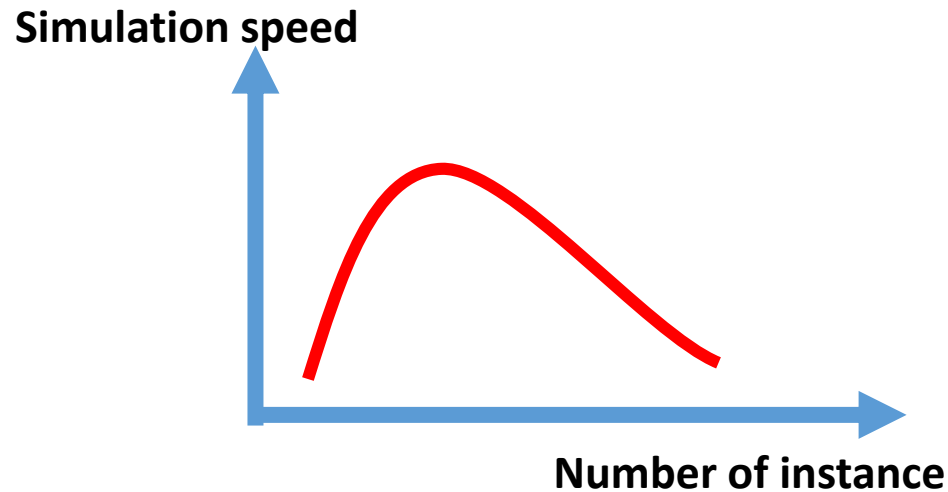
SCENARIO GENERATION



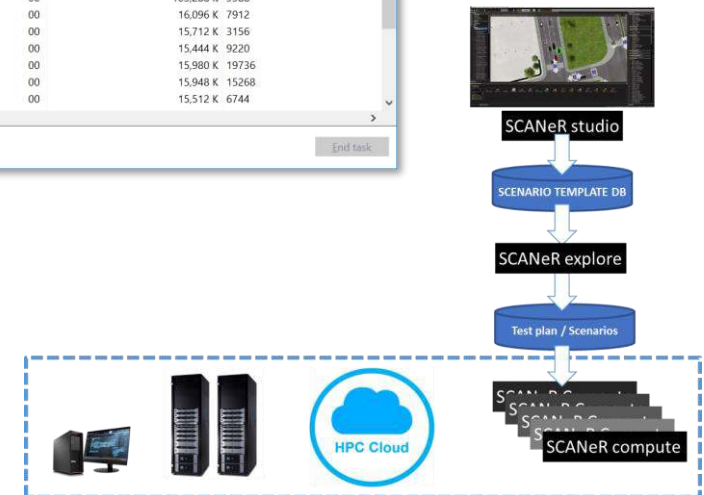
Massive parallel execution

SCANeR compute

- Solver version of SCANeR
 - Easy to deploy
 - Multiple instances on the same node
 - Windows (Pro/Server)
 - Linux (Ubuntu LTS/CentOS 7)
 - Compatible with standard job scheduling tools (LSF, PBS, ...)



Two screenshots from a Windows operating system. The left screenshot shows the 'Task Manager' window with the 'Performance' tab selected, displaying a list of running processes including 'dasHost.exe', multiple instances of 'ModelHandler.exe', 'OfflineScheduler.exe', 'RecorderNRT.exe', 'scenario.exe', 'Sensors.exe', and 'traffic.exe'. The right screenshot shows the 'Performance Monitor' window, displaying system metrics for an AMD Ryzen 7 1800X Eight-Core Processor, including CPU usage at 91%, memory usage at 23%, and various system specifications like sockets, cores, and cache sizes.



MASSIVE SIMULATION IN THE CLOUD

Microsoft Partner

104.214.222.167:8050

90%

AVS Cloud Simulation Monitoring Dashboard

Start Stop Clear

500 scenarios played, 1570 km simulated today

Parallel coordinate graph for scenario parameters :

AvsPoolDemo

standard_d2s_v3, steady

Last resized 4 hours ago

Custom image (windows)

1 USD 0.12/h

No tags

Graphs Configuration Nodes

Pool has no nodes

idle (0)

- running (0)
- waitingforstarttask (0)
- offline (0)
- preempted (0)
- Transition states
- creating (0)
- starting (0)
- rebooting (0)
- reimaging (0)
- leavingpool (0)
- Error states
- starttaskfailed (0)
- unusable (0)
- unknown (0)

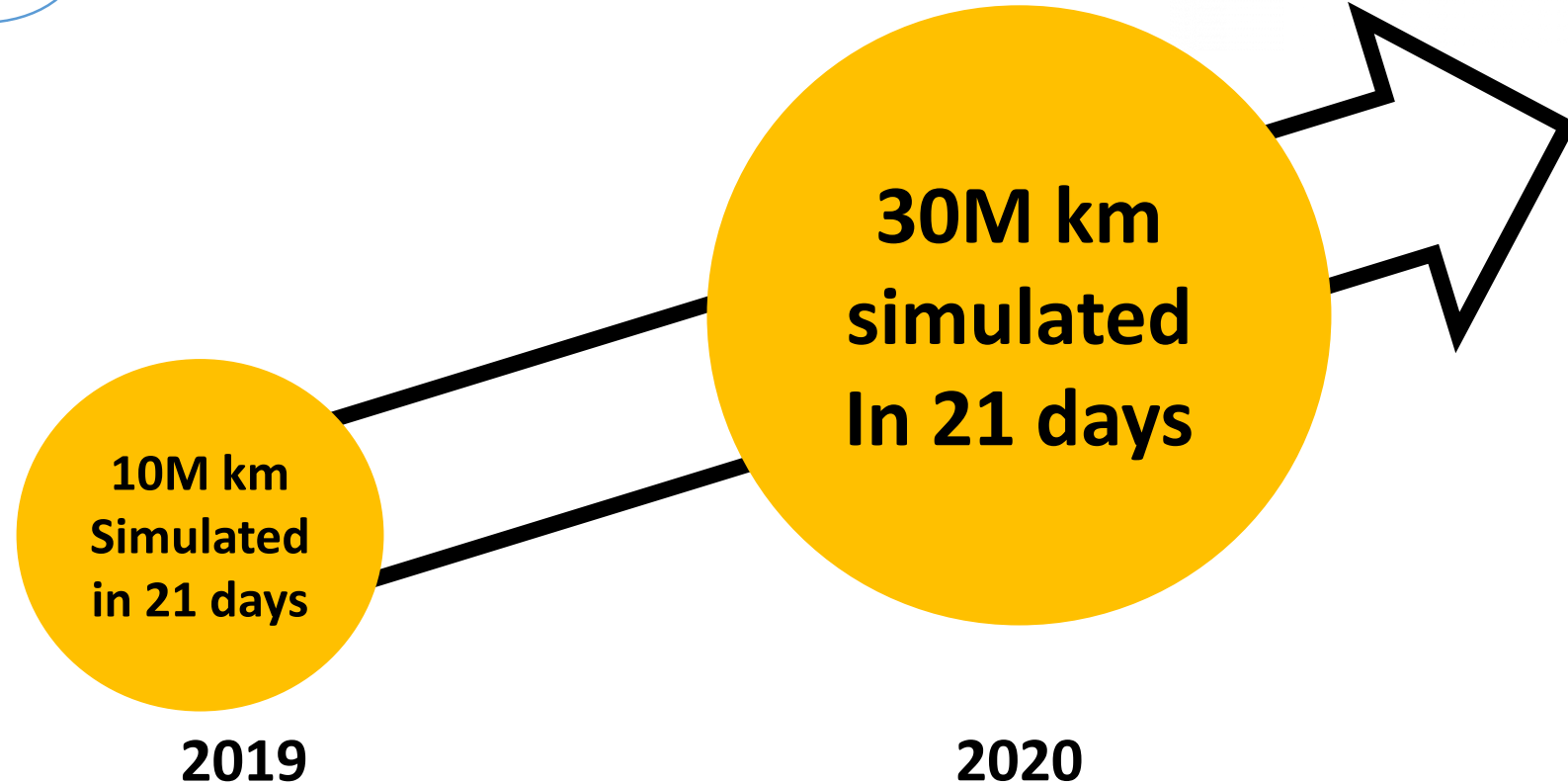
Last 10 Minutes

Results

MASSIVE SIMULATION @ GROUPE RENAULT



is deployed on Renault HPC infrastructure and cloud powered by



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Thank you

