

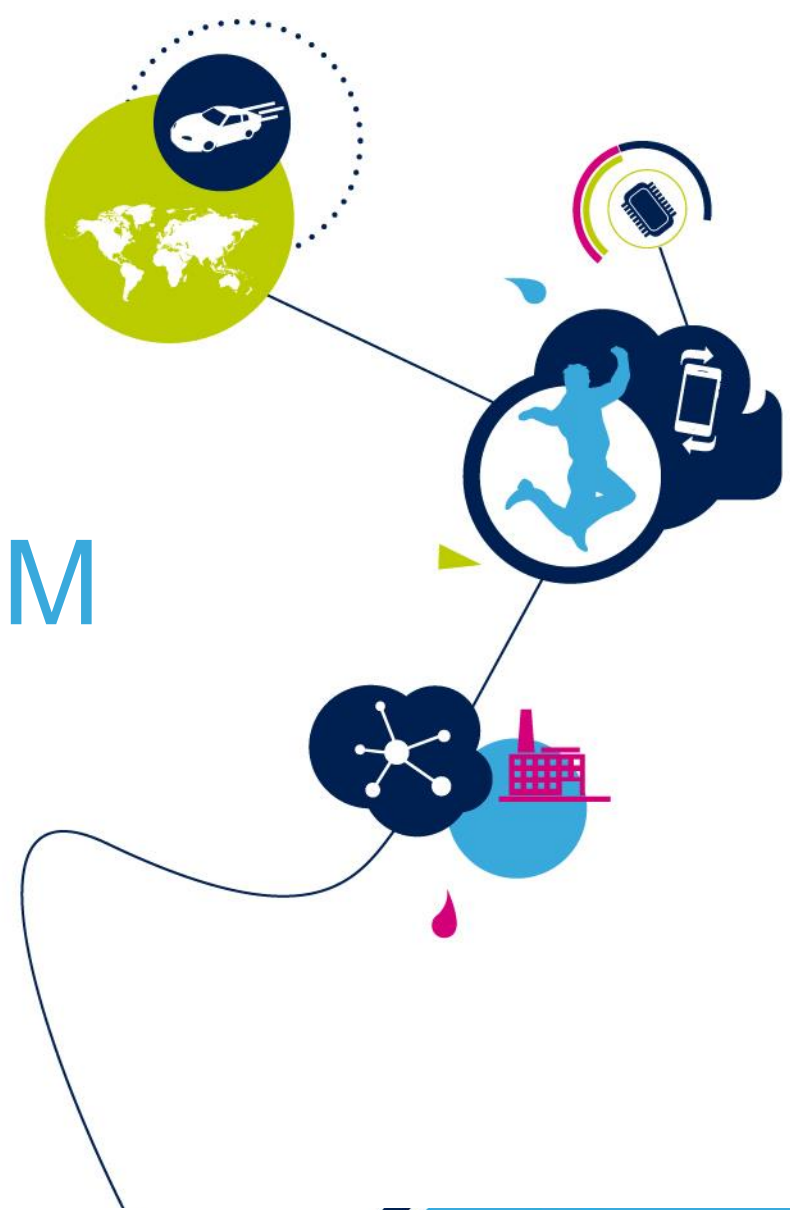
# Automotive MCUs in 28nm FD-SOI with ePCM NVM

**Roger Forchhammer**  
Director of Business Development



**ST Developers  
Conference**

September 12th, 2019  
Santa Clara Convention Center - Mission City Ballroom  
Santa Clara, CA



**Technology will redefine the driving experience, as control will be handed over to an onboard automated system.**

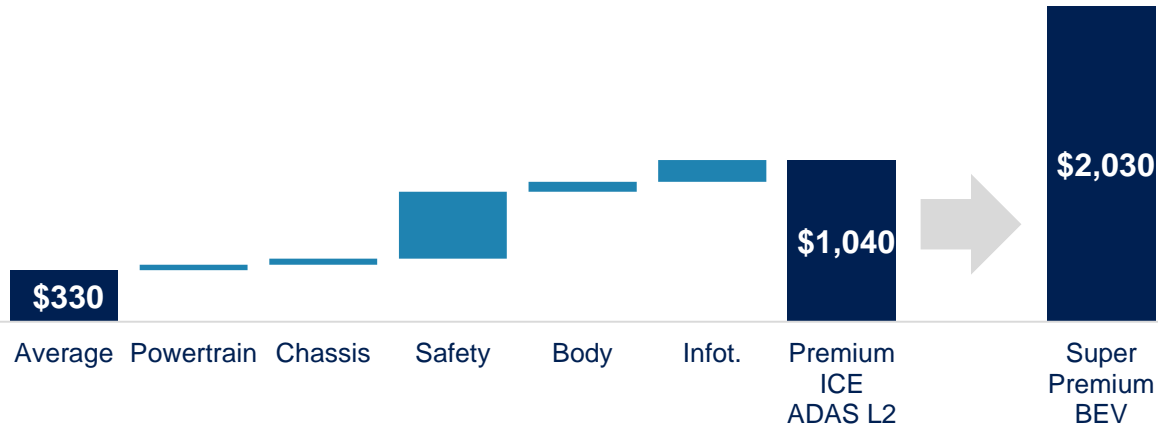
**The cars of the future will be autonomous, electric and interactive.**

# Transformational Trends: an Opportunity

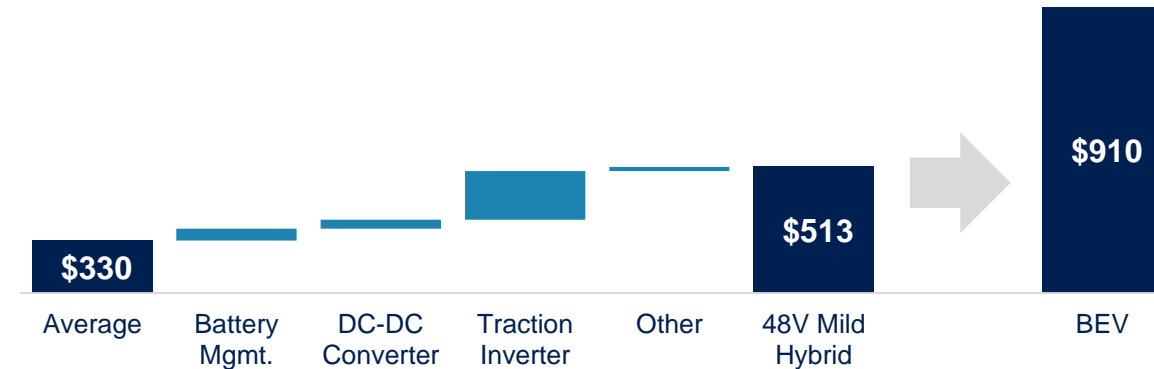
## Silicon Content (\$)

3

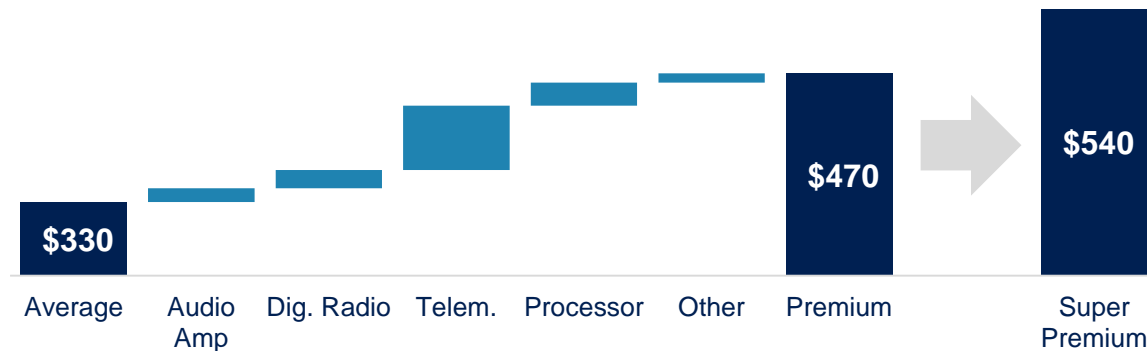
### Premium vs. Average Vehicle



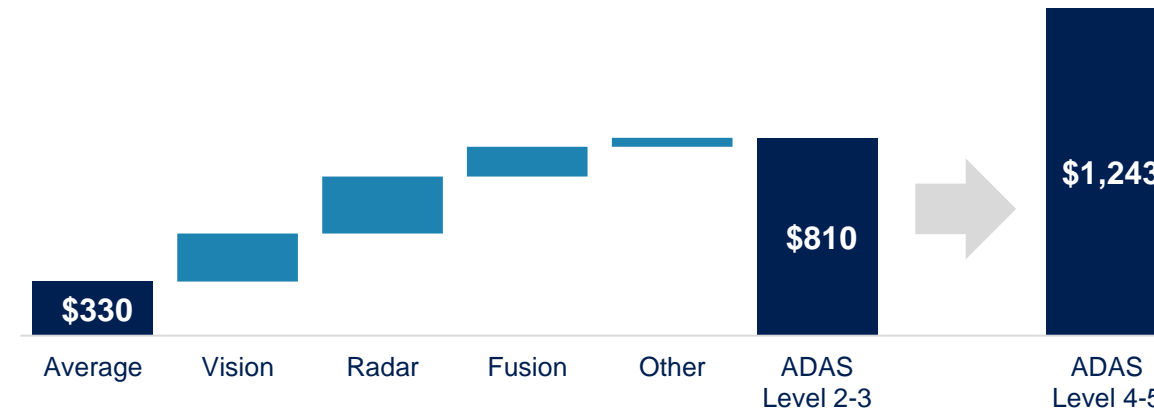
### Electrification



### Infotainment & Telematics



### Autonomous Driving



BEV: Battery Electric Vehicle

Source: Strategy Analytics and ST

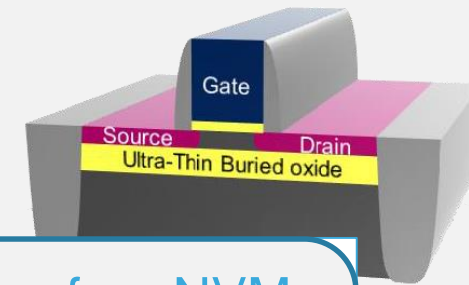
# Automotive MCUs

## New Paradigm post eFlash and bulk CMOS

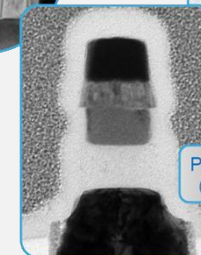
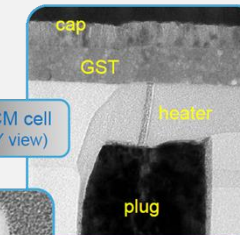
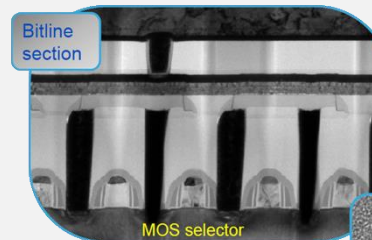
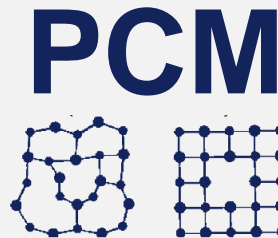
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- CMOS cost trend
  - Worsened by low logic content and less aggressive technology flavor for automotive MCUs (lifetime, environment and quality)
  - End of Moore's Law
- Flash integration cost
  - Worsens Moore's Law trend

FD-SOI for Moore's Law continuation  
Reducing cell size  
With Excellent leakage performance



PCM for Moore's Law continuation for eNVM  
With numerous additional benefits



# FD-SOI: Innovative planar process technology

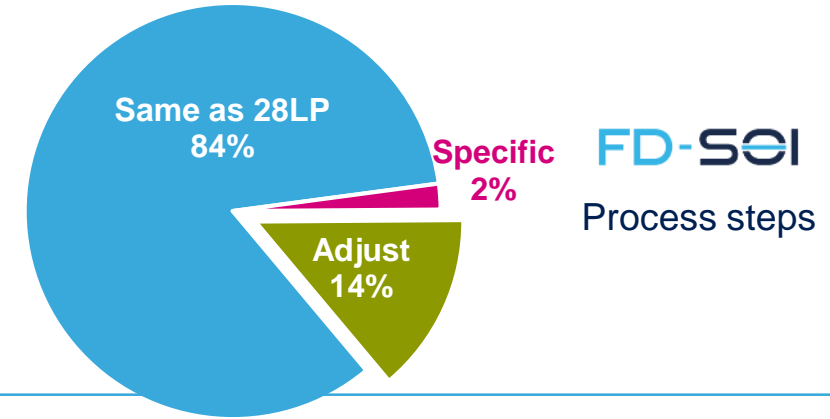


# FD-SOI for Digital & Mixed-Signal SoCs

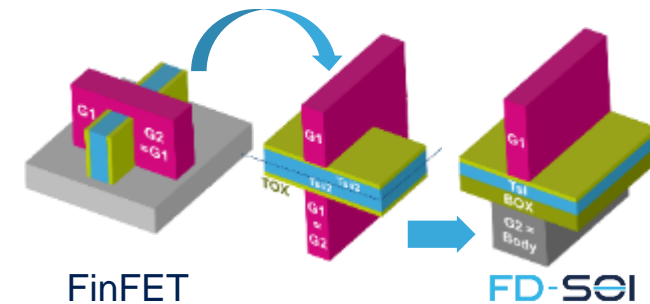
6

- ST **pioneered** FD-SOI technology & developed complete **Ecosystem**
- ST is now **Deploying** Products
- FD-SOI Key Factors of Merit
  - Power Efficiency
  - Analog / RF Design
  - Robustness

FD-SOI re-uses most of 28LP planar manufacturing



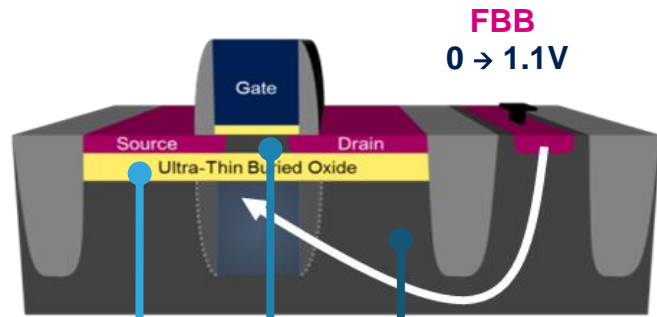
FD-SOI & FinFET:  
Fully depleted transistors but different rotation





# Fully depleted Silicon-on-Insulator (FD-SOI)

7



FBB  
0 → 1.1V

Total dielectric isolation

No channel doping

No pocket implant



**Power and energy efficiency**

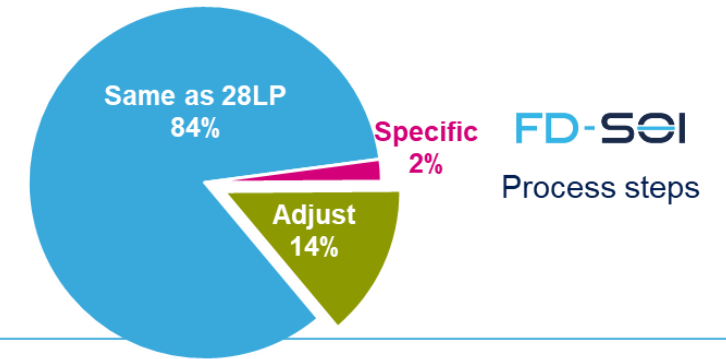


**Analog performance**  
for mixed signal and RF design

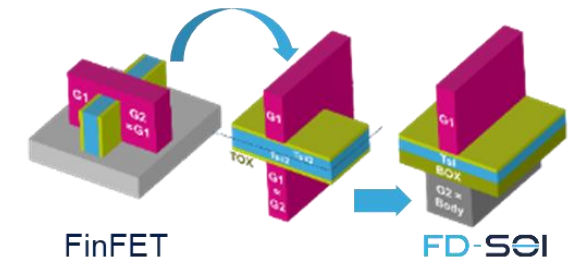


**Robustness**  
for mission critical applications

FD-SOI re-uses most of 28LP planar manufacturing



FD-SOI & FinFET:  
Fully depleted transistors but different rotation



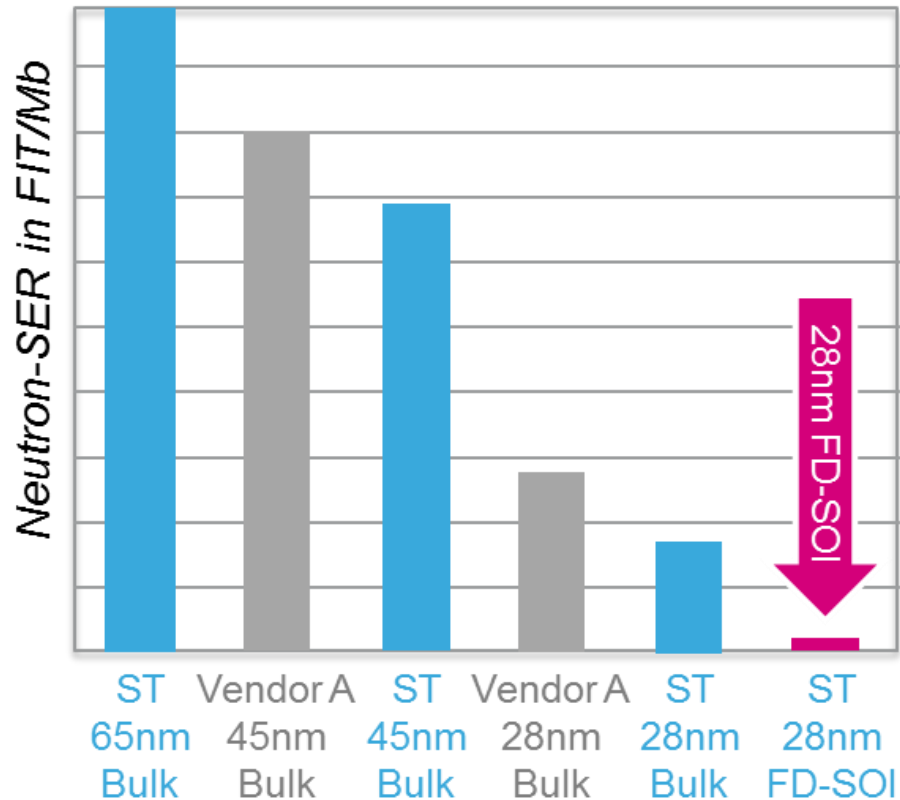
FD-SOI is unmatched for **energy-efficient** applications requiring digital and Mixed-Signal SoC **integration and performance**

# M28 Technology

## FD-SOI quasi-immunity to radiation

8

Experimental Soft Error Rate data



- Latch-up Immunity
- Larger Integrated Memory
- Simpler rad-hard designs
- ECC not mandatory → Power and Area saving

SER gain vs.BULK

	FD-SOI	FinFET
Alpha	1000×	15×
Neutron	100×	10×
Latchup	immune	at risk



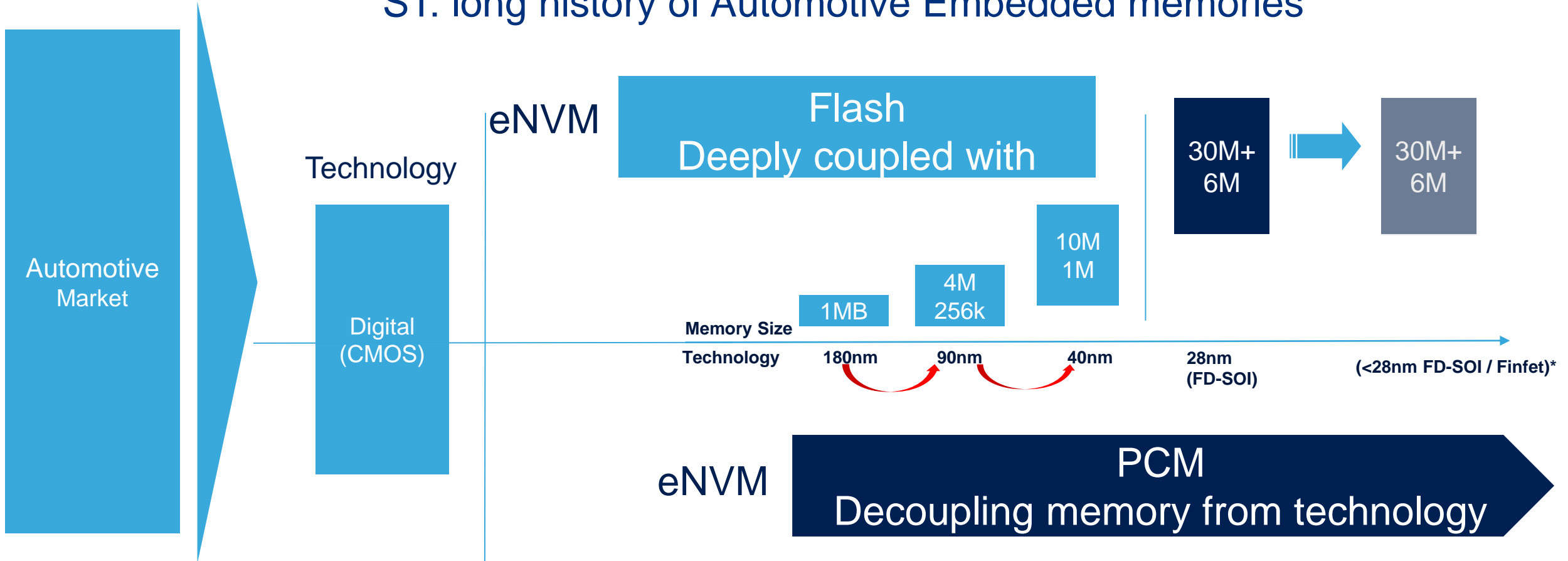
# PCM: Innovative Embedded Memory



# ST Automotive MCU Embedded Memory

11

ST: long history of Automotive Embedded memories



PCM is back-end of line process:

- No impact of transistor process flow & CMOS / BCD performance
- Suitable for CMOS and also BCD

# PCM (Phase Change Memory) Concept

11

- Storage Mechanism

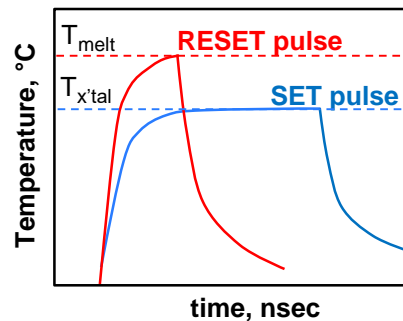
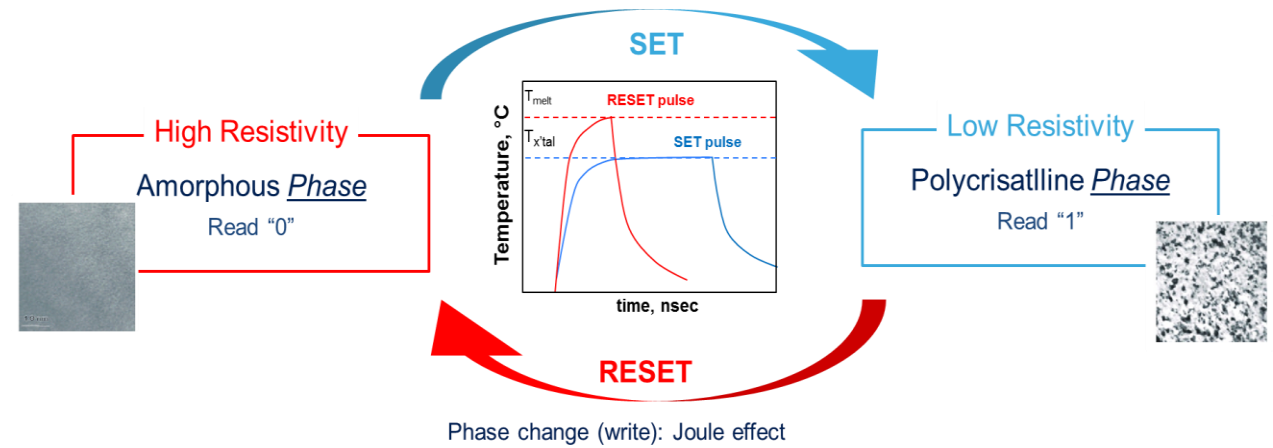
- Material with variable resistance  $\text{Ge}_2\text{Sb}_2\text{Te}_5$  (GST)
- Switch between amorphous / poly-crystal phases

- Reading Mechanism

- Resistance change of the GST

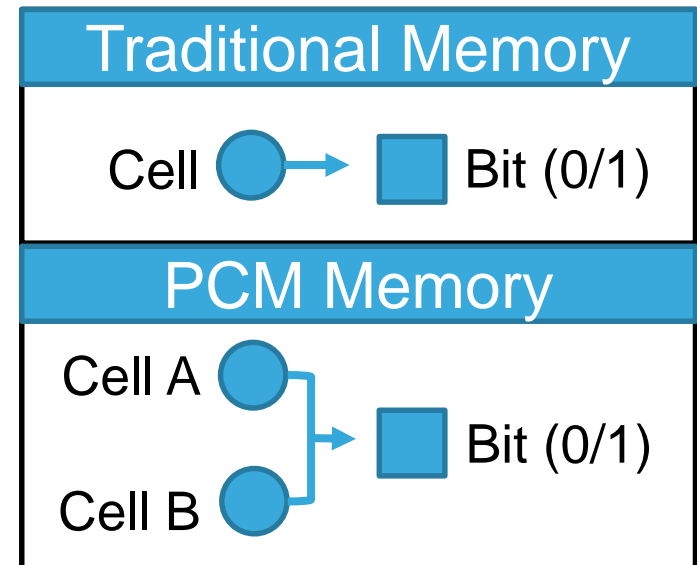
- Writing Mechanism

- Self-heating due to current flow (Joule effect)



- Implementaion for Automotive

- Two cells per bit** to grant < 1ppm @ 165C Tj

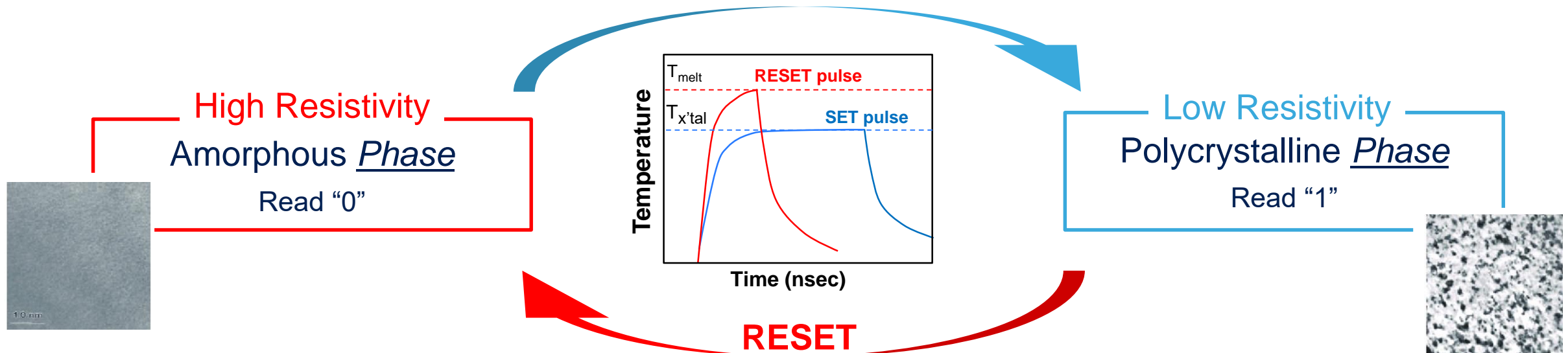


# Phase Change Memory working principle

13

Storage Mechanism: Material with Variable Resistivity

Resistivity changed via Thermal Cycles (Joule Effect)



**Read speed:** 10ns. **Write cycle:** 1M+ cycles

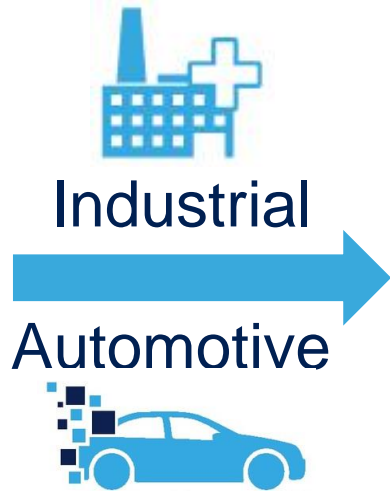
ST patented technologies:

1. PCM cell structure
2. Custom material for high-temperature support

# ST Innovation in NVM

13

for embedded processing



**Innovation  
in  
Non Volatile  
Memories**



**Innovation in  
NVM  
combination  
with Silicon  
processes**

FD-SOI  
28nm

Sampling

BCD  
90nm



Stimulate  
Customer  
Creativity

**Enable  
New  
Applications**

## PCM advantages

- High temperature capability (165° C)
- Radiation immunity
- Single-bit alterability (E<sup>2</sup>PROM like / Virtual RAM)
  - Enable delta SW update
  - Simple, safe, performing use of NVM program space for dynamic data storage
- Embedded PCM enables multi-process portability

## PCM enables new technology platforms

### FD-SOI (28nm)

- Computational real-time performance
- Power efficient: 6000+DMIPS with no heatsink
- Large embedded memory arrays (16-32Mbyte)

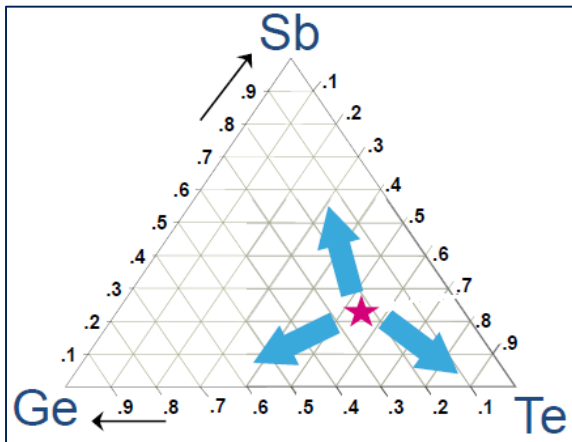
### BCD (90nm)

- single IC processing, sensing, power

# ePCM Development Challenges

16

- Automotive ePCM Challenge: Temperature
  - AECQ-100 Grade 0 requires product operates at temperature of 165° Taj
  - Data Retention after soldering reflow (2 min. at 260° C)



Patent Pending – Details Avail  
Under Non-Disclosure Agreement

- $\text{Ge}_2\text{Sb}_2\text{Te}_5$  crystallization temperature  $\sim 150^\circ\text{C}$ 
  - Consolidated in industry
  - Automotive Requirements: **FAIL**



ST patented a modified  $\text{Ge}_x\text{Sb}_y\text{Te}_z$  alloy

- crystallization temperature increased to  $\sim 370^\circ\text{C}$
- Automotive requirements: **PASS**



ST provides ePCM supporting up to 165°C and soldering compliant

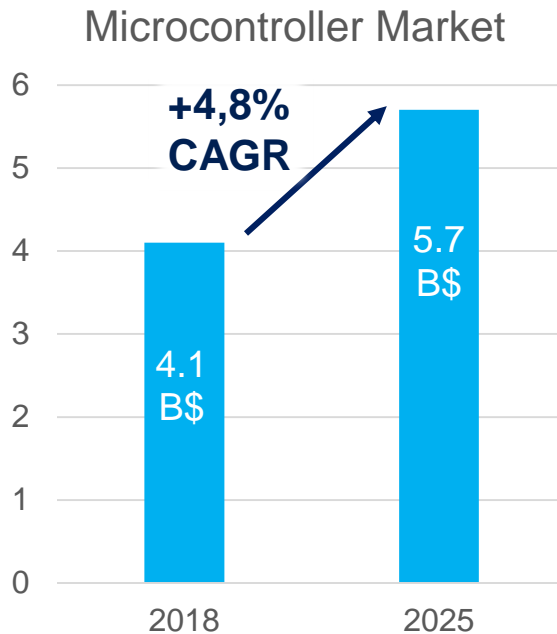
# Automotive MCU Market & Challenges



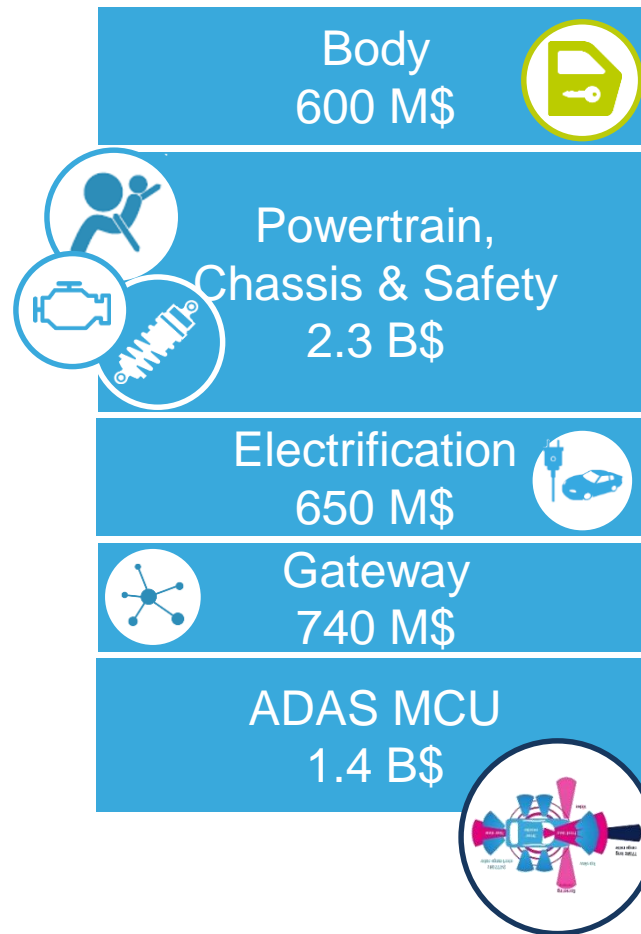


# Automotive Microcontrollers

16



\*Source: Strategy Analytics



## Automotive MCU growth contributors:

**Advanced Powertrain:** combining Electric Motors, Thermal Engine and Transmission management

**Electrification:** smart power supporting electrification

**Gateways:** Secure communication interfaces

**ADAS:** safety microcontrollers

eNVM trend: increase memory size due to:

- increased software complexity
- multiple firmware-image storage

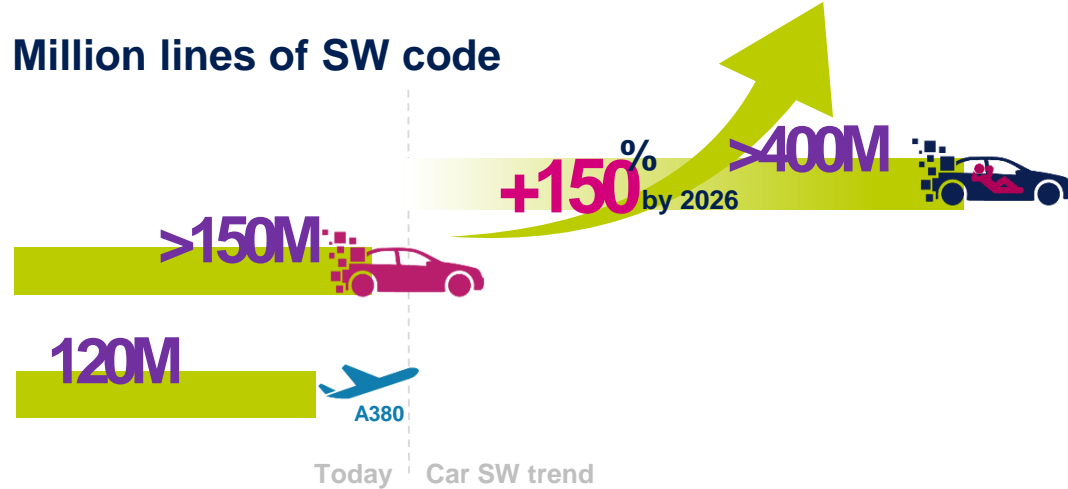
# Vehicle SW Content growing quickly

## Challenges and Needs

17

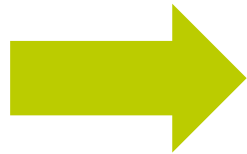
### Cars running on code

Million lines of SW code



>10%

of vehicle content  
for a large car is SW



>30%

vehicle SW content,  
2030 Projection

Up-to-date and **Secure** software essential to guarantee **vehicle Safety**

Agile and direct approach for **software update becomes mandatory**



life.augmented

Source: McKinsey, ST

### Vehicle Over-the-Air Software Update

#### Over-the Air Update (OTA)

software and feature upgrades as well as security updates

- OEM driven bug fixes – minimal time and impact
- remedy for safety or compliance issues
- enhancements for quality improvement - fuel consumption
- security patches versus new vulnerabilities
- Maintenance, subscriptions-based services



**need for real-time updates, no vehicle perturbation**

### Revolutionary Technology for uncompromised OTA

**PCM** embedded NVM in **FD-SOI 28nm**



Fast Programming, Single bit over-write



Built-in HW A/B contexts swap



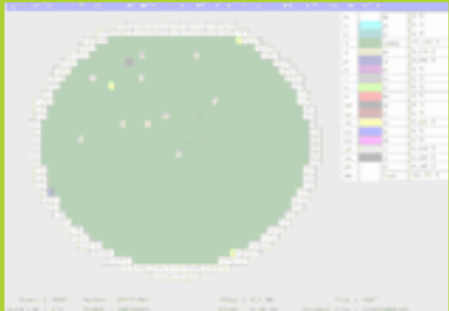
Low power



Extended Reliability

# Automotive Requirements and their manufacturing impact

18

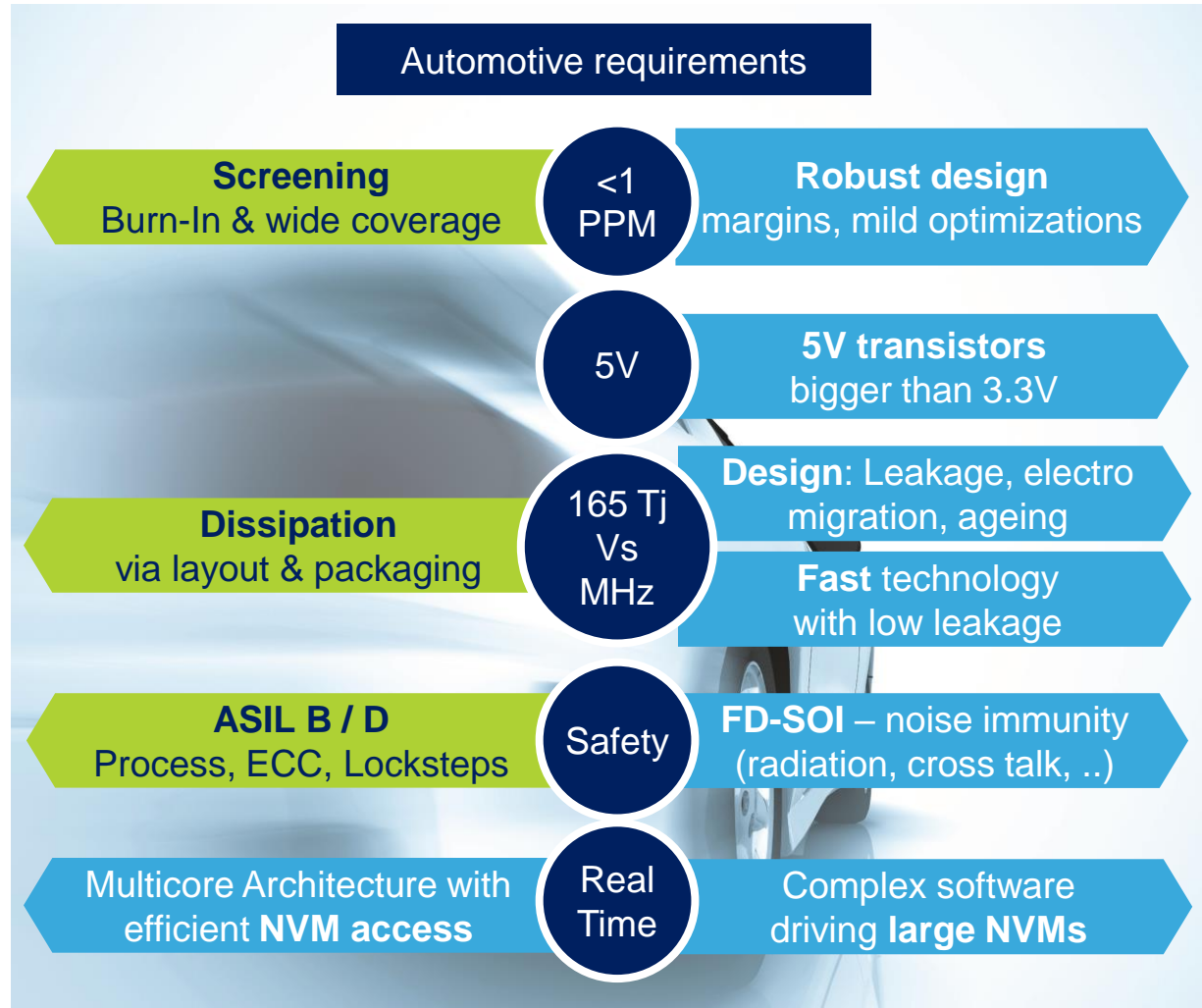


**Testing and Assembly impact**

Testing:  
Increased Test Time & additional steps

Packages: high performance  
(e.g.: exposed pad)

Complex Design cycle



**Wafer and manufacturing Impact**

Increased design & product costs

Additional masks

Advanced technology and options (FD-SOI)

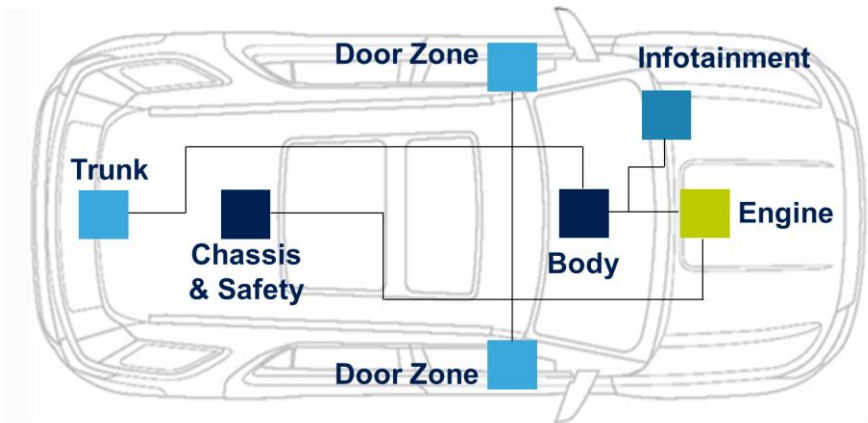
NVM for high-density technology

# The Evolution of Vehicle Architecture....

19

## ST Technology enablers: FD-SOI 28nm with PCM

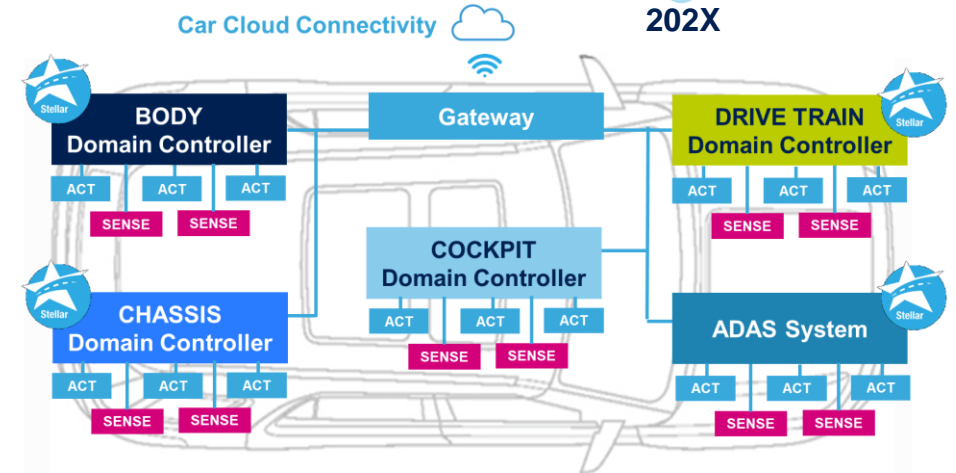
2017



x10

Car  
Computational  
Power

202X



### Distributed Architecture: 9k D-MIPs per Car

- Local Control Units up to **130 ECU/Car** (with 8-16-32bit MCU)
- Limited connectivity and in-vehicle data-flow (up to 10 Mbit/s)
- Heavy and expensive harness
- Extremely complex car Software management
- No car-functionality upgrades



### Integrated Real-time Domain Architecture: 90kD-MIPs per Car

- ~5 Domain-Control Units with higher power computation and Non-volatile Memory micros: **STELLAR** with internal Phase Change Memory (PCM)
- Autonomous Driving Super-computer (MPU ext. Memory) ~**100 Trillion Operation per second (EyeQ6)**

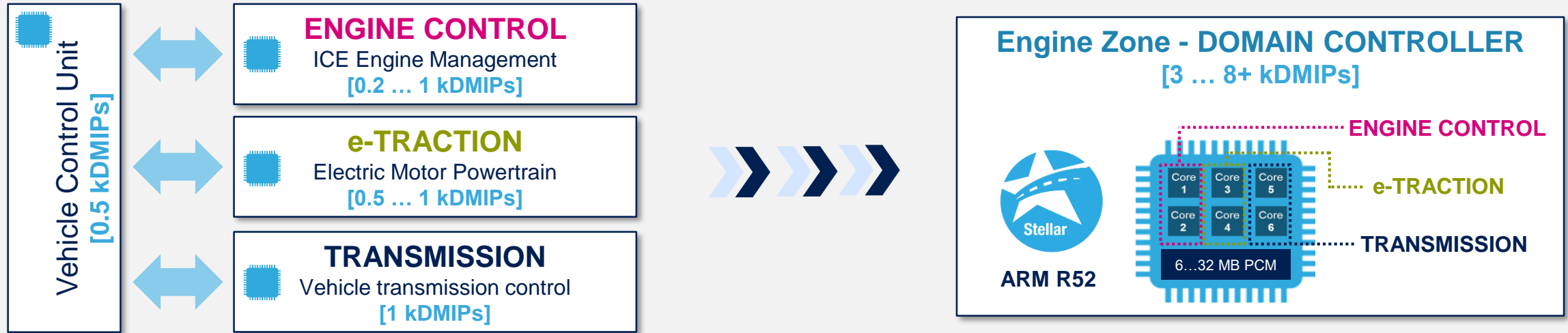


- Architecture simplification, SW rationalization, harness drastic reduction
- Easy car functionality reconfiguration and SW upgrade
- Enabling high-speed in-vehicle communication
- Over-The-Air Software capability

# ...from ECUs to Domain Control

## example: evolution for Vehicle Traction

20



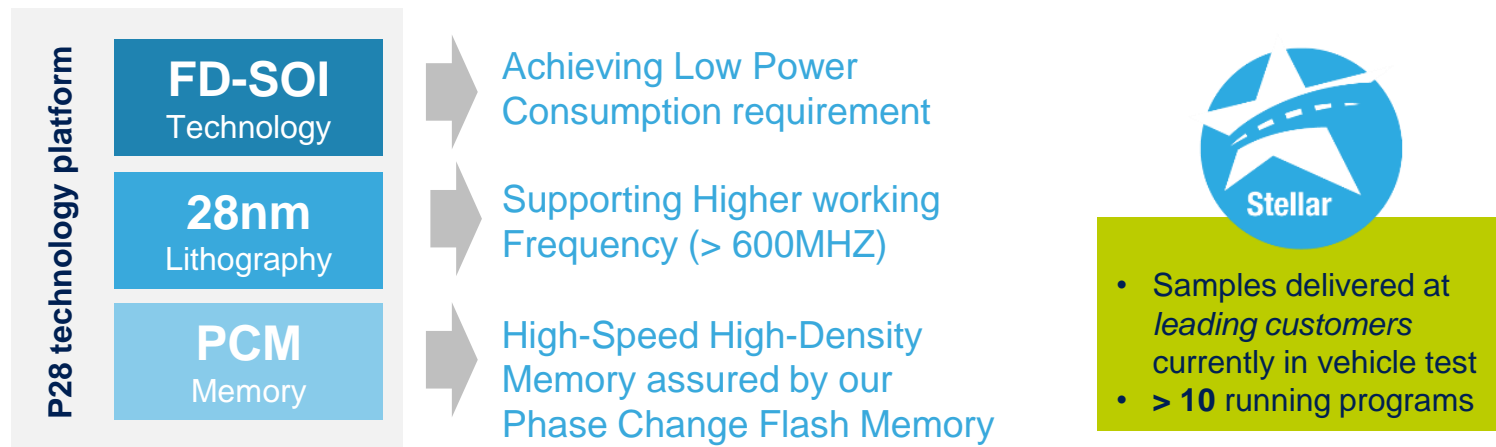
### Requirements:

- High density technology
- Real-time
- Working Frequency > 400MHz
- Low power consumption
- >16 MB of high speed access Non-Volatile Memory



### Stellar: ST 28nm FD-SOI with embedded Phase Change Memory

ST in-house production at Crolles 12 inches



# Increased Data Flows

21

Require increased security, processing power & connection speeds

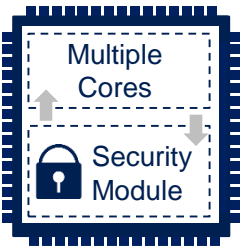
## Security

MCUs & Processors with Embedded Security

- Specific Microcontrollers dedicated to automotive, to secure all applications:

- Power Train
- Braking
- Steering
- Gateway & Connectivity
- ADAS & V2X
- Infotainment

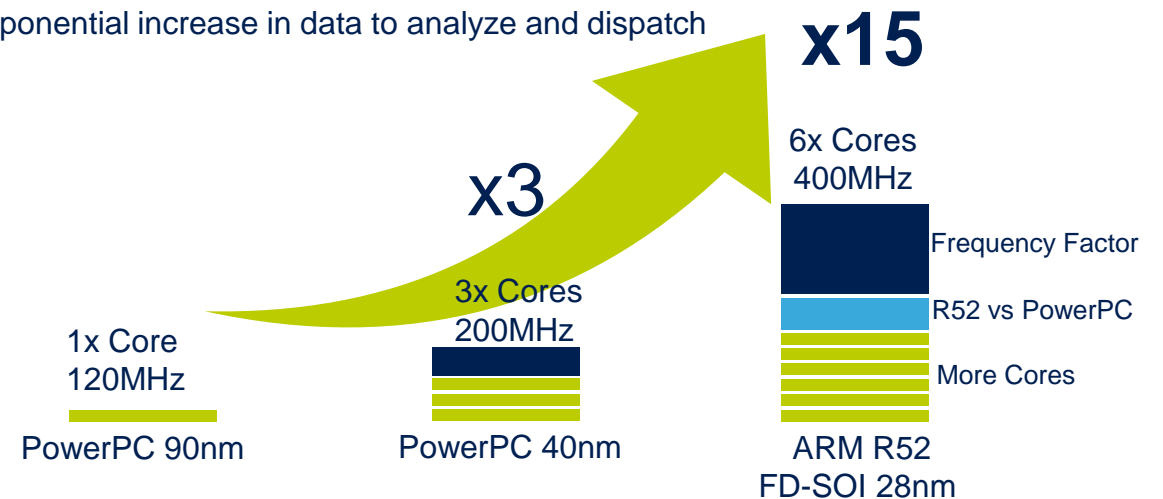
- Embedded Hardware Security Module
- Security Level (EAL3/4)
- High data-rate encryption/decryption to manage data streams



## ECU Processing Capability

Increase required in many automotive domains

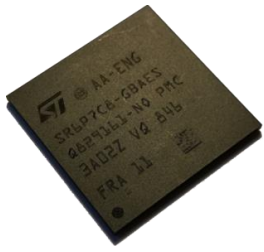
Exponential increase in data to analyze and dispatch



ST's New high-end 32-bit Automotive MCU Family will provide the power

- ARM Cortex R52, 6x Cores, 400MHz
- 16/32 Mbyte 28nm FD-SOI with embedded PCM Flash memory
- Sampling 2018





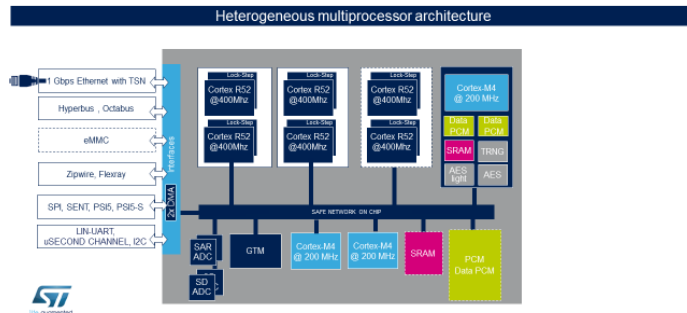
## Safe Real-Time Automotive MCU for Domain Controllers



- Multicore Arm® Cortex®-R52
- Embedded Phase-Change Memory
- ASIL-D with hypervisor
- Secure communications



### Stellar Family Architecture



# 1<sup>st</sup> Automotive MCU in FD-SOI

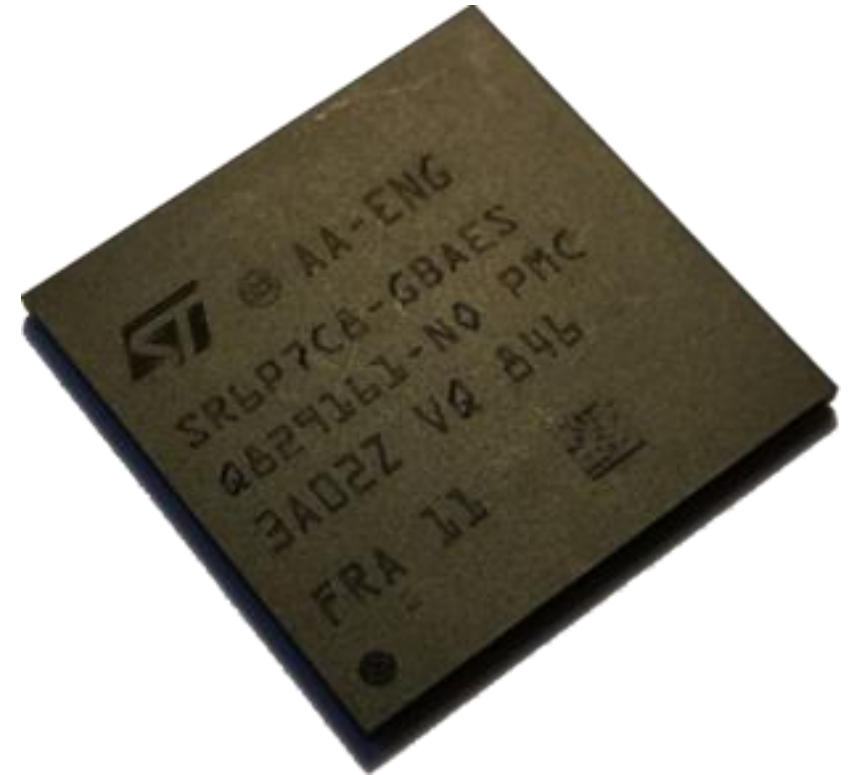
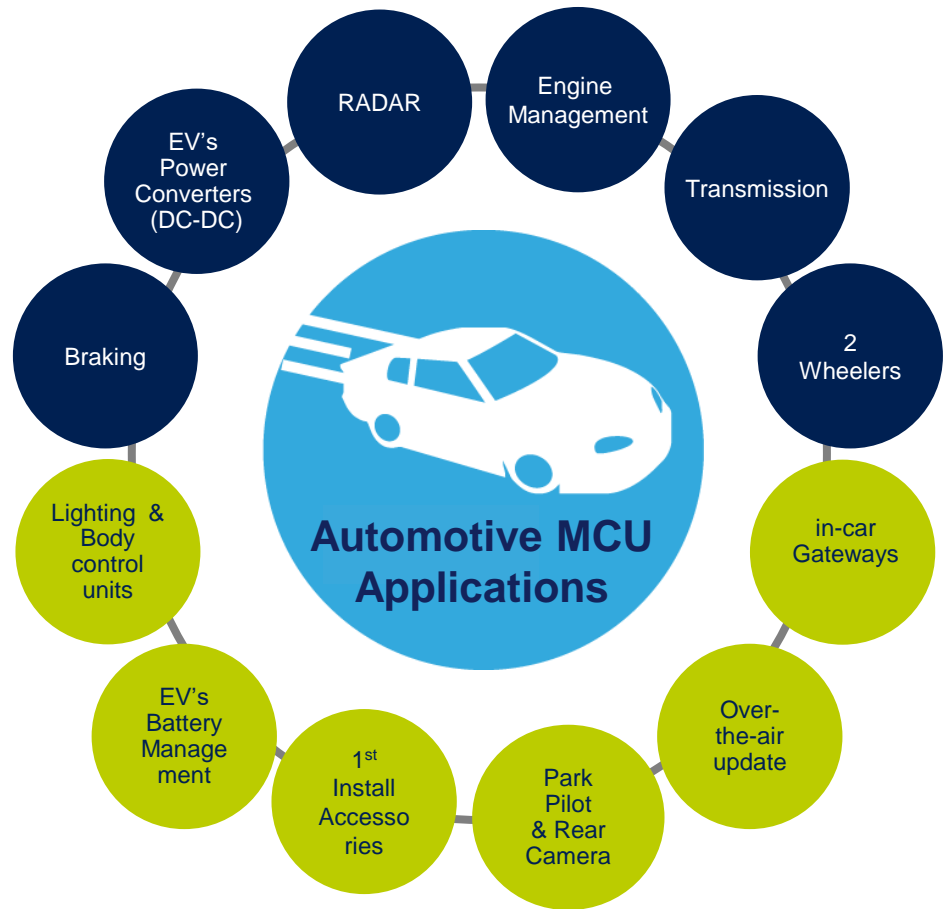
22

- STMicroelectronics Introduces the 1st Safe, Real-Time Microcontrollers for Next-Generation Automotive Domain Architectures utilizing 28nm FD-SOI and on-chip Phase Change Memory (PCM)
  - *First Arm® Cortex®-R52 automotive microcontrollers with on-chip non-volatile memory for real-time multi-core performance; With full ISO26262 ASIL-D coverage and hypervisor providing new industry reference for functional safety*
  - *28nm FD-SOI with efficient, high-temperature embedded Phase-Change Memory maximizes performance and reliability while minimizing power consumption*



# Auto MCU product in 28nm FD-SOI with ePCM

23



# MCU Chip Preliminary Results

24



- 32b processor with 6MB ePCM processed in 28FD-SOI with ePCM technology
- Running in the car, replaces the previous generation (40nm eFlash) product
- <12ns Random access time (@165°C)
- 0.8MB/s code modification speed
- No sector erase needed prior to programming
- Passes JEDEC soldering tests, proven on customer board, too
- 100k PCM writing cycles demonstrated
- Passing 2000 hours retention tests at 150°C

- Automotive market is in continuous expansion, with growing silicon content in cars
- ST is an undisputed leader in the automotive market, with a global offer covering all the needs
- ST is pioneering and driving new technologies into the automotive market
- Increased data flows in automotive is demanding higher performances and memory quantity to automotive MCU
- 28nm FD-SOI with embedded PCM NVM memory is the answer to this demand, for offering energy efficient high performance cores with ultra dense NVM memories, qualified up to auto grade-0



# Thank you

ST stands for  
**life.augmented**

Everywhere  
microelectronics make a  
positive contribution to  
people's lives, ST is  
there