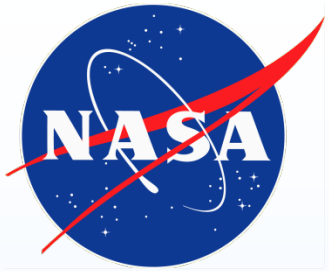

The NASA Electronic Parts and Packaging (NEPP) Program: Memory and Advanced Processor Plans

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NASA/GSFC

http://nepp.nasa.gov

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Acronyms

Acronym	Definition
ADC	Analog to Digital Converter
AFRL	Air Force Research Laboratory
ASIC	Application Specific Integrated Circuit
CAN-FD	CANbus Full Duplex
CBRAM	Conductive Bridging Random Access Memory
CRC	Computer Resource Center
CSE	Computer Security
CU	Control Unit
DCU	Data Collection Unit
DDR3	Double Data Rate Third Generation
DDR4	Double Data Rate Fourth Generation
DIMM	Dual In-line Memory Module
DMA	Direct Memory Access
DRAM	Dynamic Random Access Memory
Dual Ch.	Dual Channel
ECC	Error Correcting Code
eLBC	Enhanced Local Bus Controller
FCCU	Fault Collection and Control Unit
FeRAM	Ferroelectric RAM
FPGA	Field Programmable Gate Array
FY	Fiscal Year
Gb	Gigabit
GE	General Electric Corporation
GPIO	General Purpose Input/Output
GPU	Graphics Processing Unit
GSFC	Goddard Space Flight Center
HDR	High Data Rate
HMC	Hybrid Memory Cube
HP Labs	Hewlett-Packard Laboratories
JPEG	Joint Photographic Experts Group
L-mem	L-Memory
M/L BIST	Memory/Logic Built-In Self-Test (BIST)

Acronym	Definition
MB RAM	Megabit Random Access Memory
Mgr.	Manager
Mil/Aero	Military/Aerospace
MIPI	Mobile Industry Processor Interface
MPU	Micro-Processing Unit
MRAM	Magnetoresistive Random Access Memory
NAND	Negated AND or NOT AND
NASA	National Aeronautics and Space Administration
NEPP	NASA Electronic Parts and Packaging
NGSP	Next Generation Space Processor
NVMs	Non-Volatile Memories
PCI	Peripheral Component Interconnect (personal computer bus)
pJ/bit	Picojoule per bit
Pref.	Performance
Proc.	Processor
RAID	Redundant Array of Independent Disks
RAM	Random Access Memory
ReRAM	Resistive Random Access Memory
RGB	Red-Green-Blue (color model based on additive color primaries)
RH	Radiation Hardened
SAR	Successive Approximation Register
SATA	Serial Advanced Technology Attachment (hard disk interface)
SD/MMC	Secure Digital Multimedia Card
SD-HC	Secure Digital High Capacity
SEC	Second(s)
SOC	System on a Chip
SPI	Service Provider Interface
SSRs	Solid State Recorders
SWaP	Size, Weight, and Power
TSVs	Toll Switching, Voice Switching
USB	Universal Serial Bus
VNAND	Vertical NAND

Talk Overview

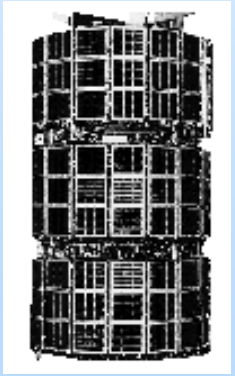
- **This talk will provide further detail on the NEPP roadmap efforts for memory devices/technologies and processors (high performance).**
  - **This includes rationale for the approach we are taking.**
- **What's not included here are but will be elsewhere during this meeting:**
  - **System on a chip (SOC) Field Programmable Gate Arrays (FPGAs) that have embedded processors, nor,**
  - **Microcontrollers/mobile processors.**

Once upon a time…

- **There once was a fledgling memory used for space**
  - **It started out as core memory (60's-70's)**
  - **Grew into magnetic tape (70's-80's)**
  - **And has settled into "silicon" solid state recorders or SSRs (90's and beyond)**
    - ***While this is true for mass data storage, silicon has been used since the 70's for some memory applications such as computer programs and data buffers***
    - ***Both volatile and non-volatile memories (NVMs) are used***

Apollo Guidance Computer

- 4 kB of Magnetic core r/w memory



P87-2 circa 1990

- 1st known spaceflight SSR

Typical Examples of Memory Usage for Space

- **Computer program storage**
  - **Boot, application, safehold**
  - **Often a mix of volatile and non-volatile memories**
    - **Store in NVM, download to RAM after processor boot, then run out of RAM**
      - ***Size, Weight, and Power (SWaP)* – RAM is faster than NVM**
- **Temporary data buffers**
  - **Accommodates burst operations**
- **Data Storage such as SSR**
  - **E.g. mass storage area for science or spacecraft telemetry**
  - **Usually write once an orbit, read once an orbit**
  - ***Trend to want to use NVM for SSR***
- **Configuration storage for volatile Field Programmable Gate Arrays (FPGAs)**
  - **Becoming a *bigger* problem as RAM-based FPGAs increase their needs**

How NEPP Views Memories

- **Evaluate radiation tolerance and/or reliability of**
  - **Highly scaled (i.e., large number of bits) memories, and,**
  - **New technology device technologies such as resistive, emerging magnetic, or carbon/graphene-based devices.**
    - **As a minimum, samples must be on path to commercialization.**
    - **We often work with manufacturers and other agencies when possible.**
- **Develop qualification and usage guidance and support transitions to Mil/Aero grade products.**

Commercial Memory Technology

Other
- MRAM
- FeRAM

TBD – (track status)

Resistive
- CBRAM (Adesto)
- ReRAM (Panasonic)
- ReRAM (Tezzaron)
- TBD (HP Labs, others)

Radiation and Reliability Testing

Radiation and Reliability Testing

Radiation and Reliability Testing

TBD – (track status)

DDR 3/4
- Intelligent Memory (robust cell twinning)
- Micron 16nm DDR3
- TBD – other commercial

Radiation Testing

Radiation Testing *Reliability Testing*

TBD – (track status)

FLASH
- Samsung VNAND (gen 1 and 2)
- Micron 16nm planar
- Micron hybrid cube
- TBD - other commercial

Radiation and Reliability Testing

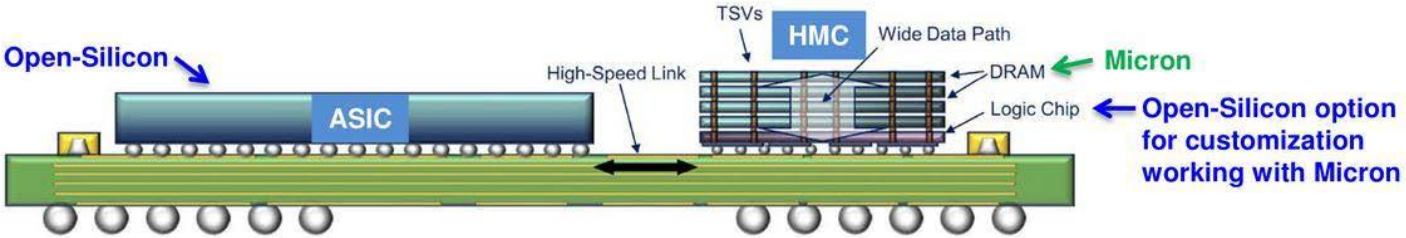
Radiation and Reliability Testing

Radiation and Reliability Testing

TBD – (track status)

FY14 **FY15** **FY16** **FY17**

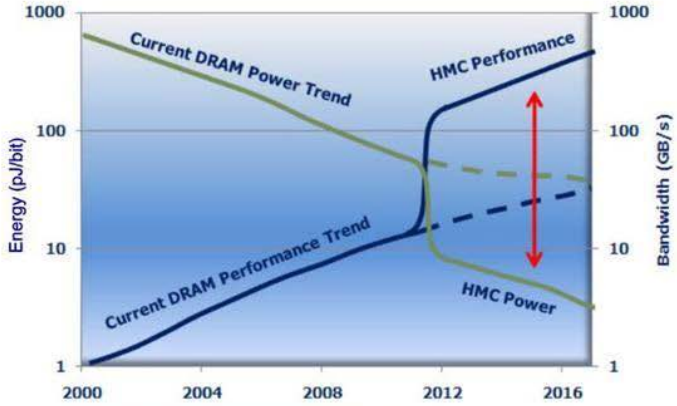
Hybrid Memory Cube (HMC) with Micron



- **HMC Benefits:**
  - ~20 times the performance of a DDR3 DIMM
  - ~10% of the energy per bit compared to current DIMMs

Power is a premium in space

	Bandwidth	Power	W / GBs
DDR3-1333	10.66 GB/s	5.52 W	518 x
DDR4-2666	21.34 GB/s	6.60 W	309 x
HMC (4 DRAMs)	128.00 GB/s	11.08 W	87 x



4 DRAM chips stacking | Through Silicon Via

CONFIDENTIAL

Open-Silicon

http://www.hpcwire.com/2014/06/24/micron-intel-reveal-memory-slice-knights-landing/

How NEPP Views Advanced Processors

- **Evaluate radiation tolerance and/or reliability of**
  - **Advanced process node processors (technology information gathering), and,**
  - **Devices and architectures that might have application to NASA and the aerospace community.**
- **Develop qualification and usage guidance and support transitions to Mil/Aero grade products (if any).**
  - **Please note that there is NOT currently a NEPP authorized document on processor radiation testing. The NEPP System on a Chip (SOC) should be used as reference and initial guidance.**

Advanced Processors

Next Generation Space Processor (NGSP)

- Joint NASA-AFRL Program for RH multi-core processor
- TBD architecture/process

RH Processor

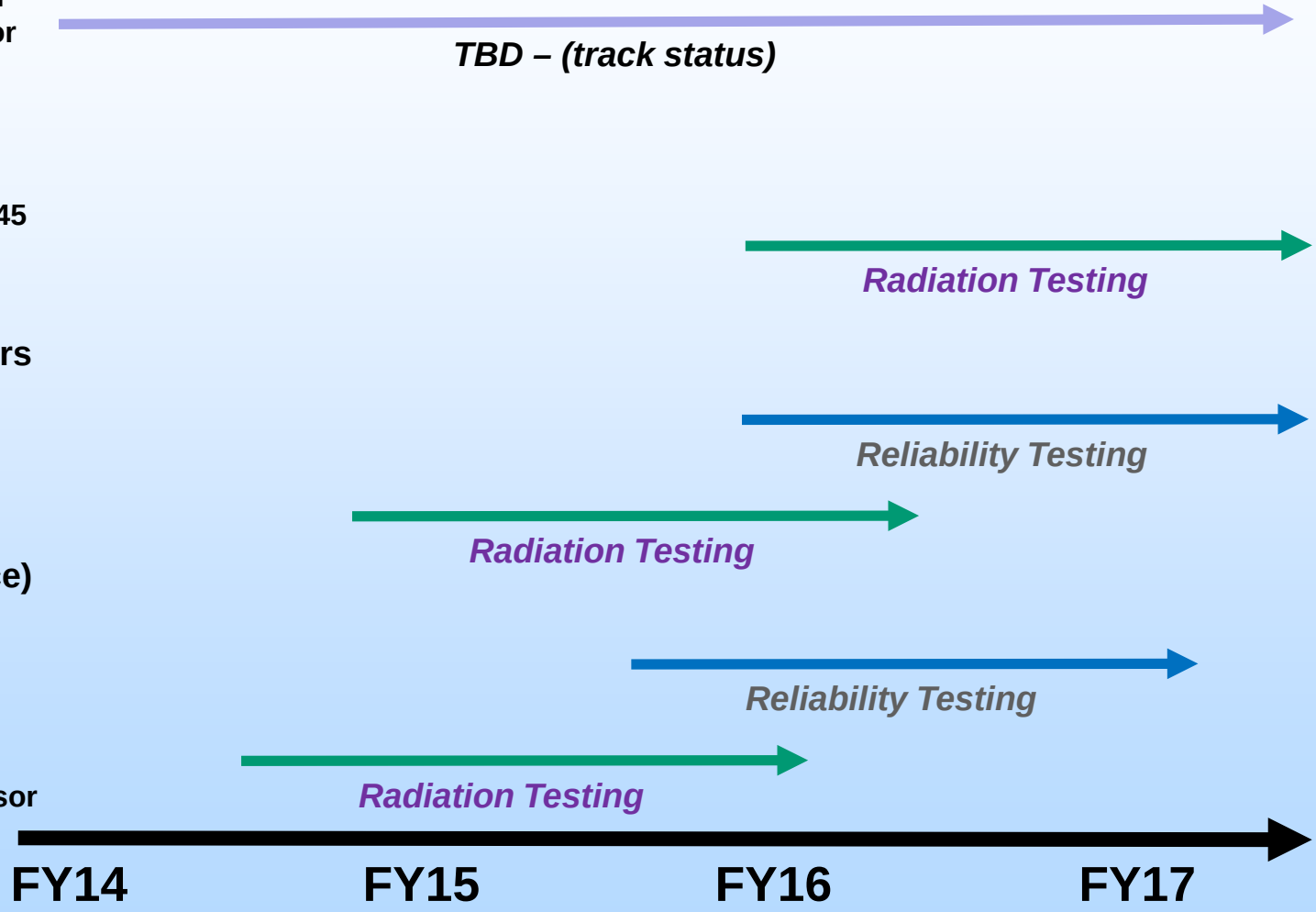
- BAE Systems RAD5510/5545
- Replacement for RAD750

Intel Broadwell Processors

- 14nm FinFET commercial
- 1st high-performance sans heatsink (lower power for performance)

Freescale P5020/5040

- Commercial 45nm network processor
- Preparation for RH processor



Note: Future considerations under discussion include automotive "self-driving" processor options.

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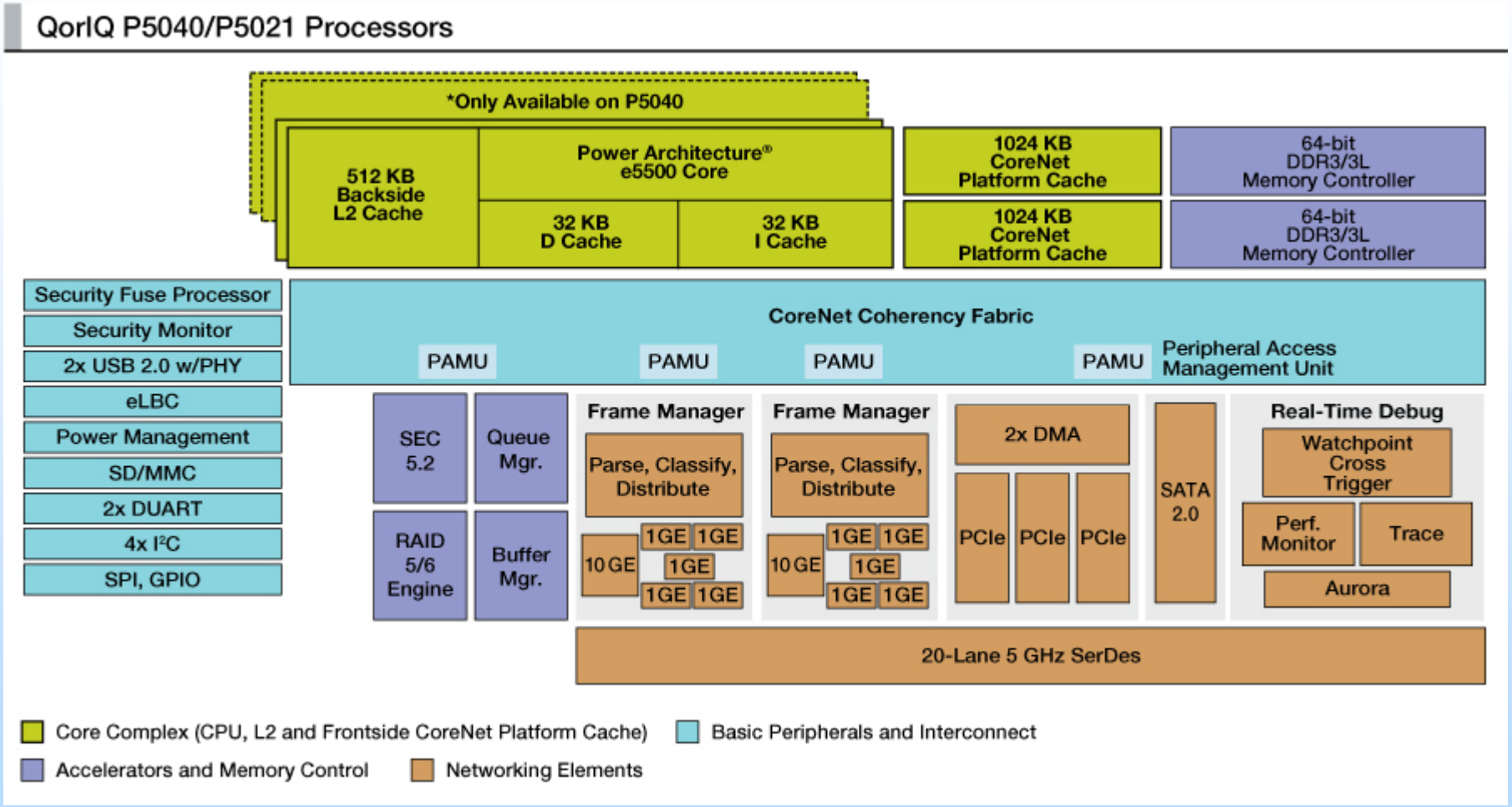
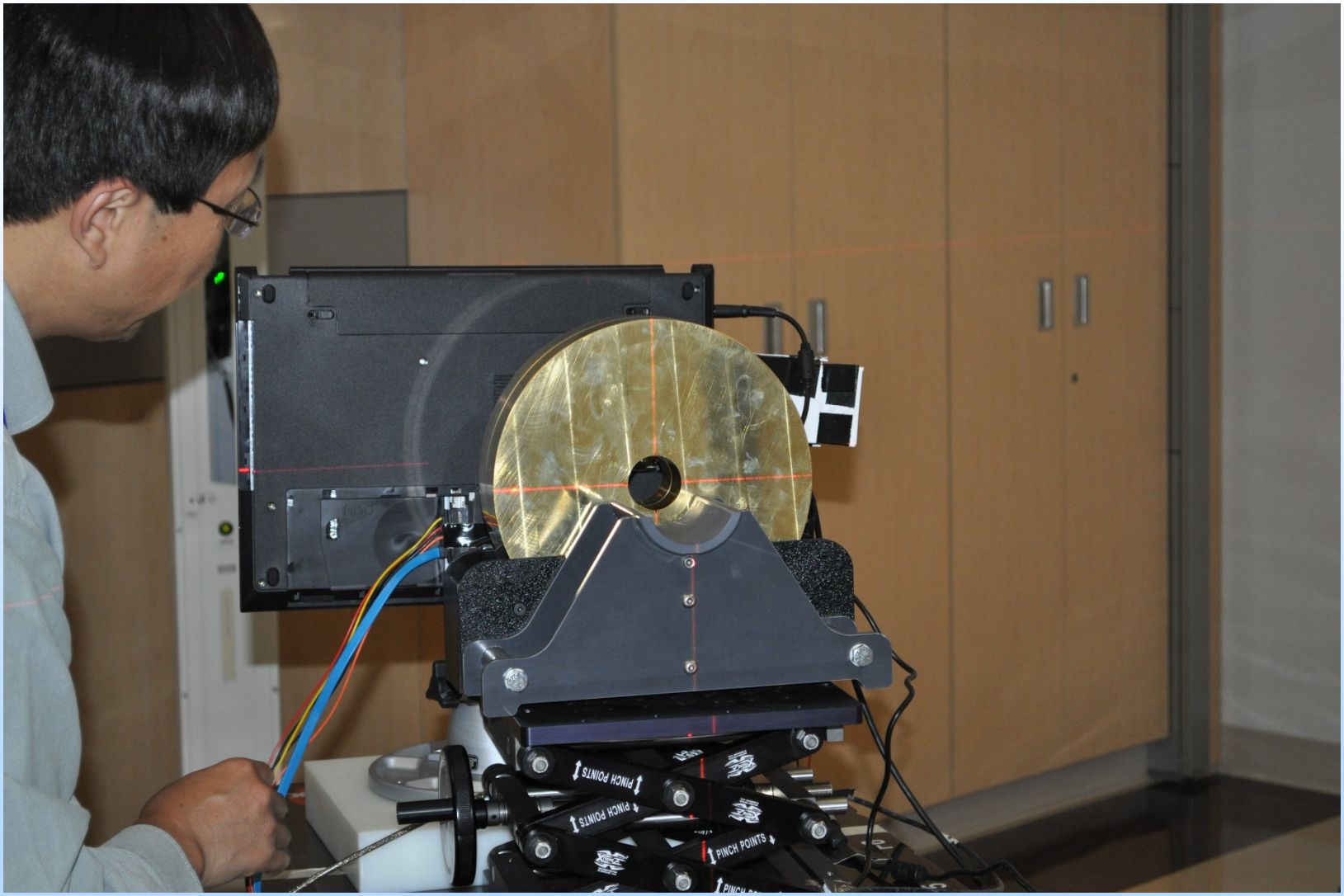
Freescale QorIQ™ P5040 Processor



Preliminary Radiation testing of 14nm Intel Processors



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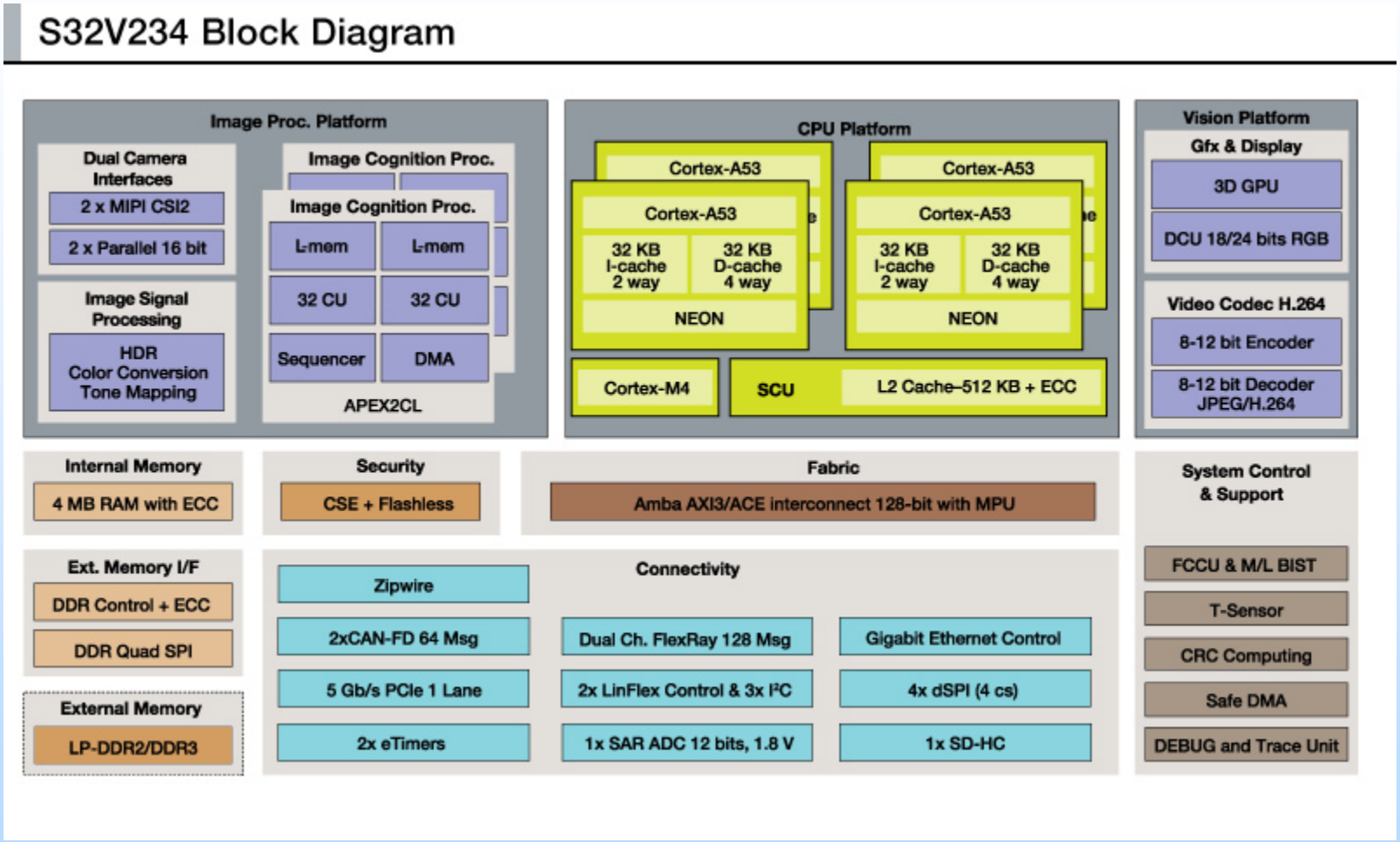
Automotive Processors and Systems for Self-Driving Cars?



From Freescale.com

QUESTIONS?

https://nepp.nasa.gov