INTERNATIONAL ROADMAP FOR DEVICES AND SYSTEMS
2023 UPDATE
BEYOND CMOS
https://irds.ieee.org/images/files/pdf/2023/2023IRDS_BC.pdf

1. Why ‘Beyond CMOS’?

-> Traditional silicon transistors (CMOS) are hitting physical limits in speed and power. The roadmap explores new materials, devices, and ways of computing that could keep improving performance for AI, data centers, and IoT.

2. What are the Big Challenges ahead?

-> Memory needs to be faster, denser, and non-volatile (keeps data without power).
-> Logic devices must switch on/off reliably at low voltages, as new channels and transistor types are studied.
-> New Architectures mix memory and logic on-chip for things like in-memory AI, cutting the need to move data around.

3. What are the Next-Gen Memories?

-> Spin-based (MRAM): Already in production, very fast, and low power.
-> Ion-driven (OxRAM/CBRAM): Changes resistance with tiny ion movements for in-memory computing.
-> Phase-change & Molecular: Store data in material phases or molecules for very high density.

4. What are some Novel Logic Devices?

-> D Materials & Carbon Nanotubes: Atom-thin channels that could work at lower voltages.
-> Tunnel & Negative-Capacitor FETs: Use quantum effects or special gate dielectrics to jump below today’s voltage limits.
-> Spin-Wave & NEM Relays: Leverage magnetism or nano-mechanics for zero-leakage switching.

5. Device + Architecture Co-Design

-> Instead of swapping in a new transistor under an old CPU, researchers design devices and chips together. Examples include analogue crossbar arrays (where memory does math) and spiking neural nets that mimic brain signals for super-efficient AI.

6. Materials & Integration

-> Building “Beyond CMOS” chips means stacking different materials safely, in the back end of the line, without damaging existing layers. New measurement and modeling tools guide choices down to atomic scales.

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7. Where do we stand & Next Steps?

-> Benchmarks show promise for energy-delay improvements in both standard ALUs and AI kernels. Key gaps remain in reliability, variability control, and moving lab demos into high-volume manufacturing.