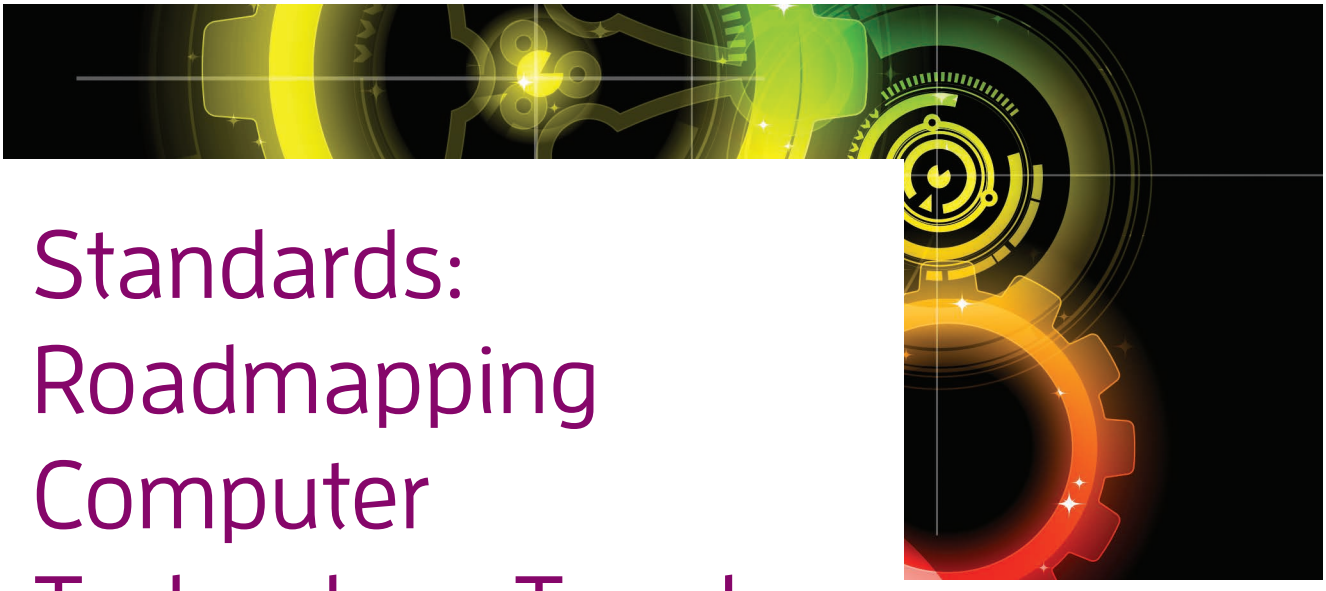

Standards: Roadmapping Computer Technology Trends Enlightens Industry

F.D. Wright, Standards Strategies, LLC

Thomas M. Conte, Georgia Institute of Technology

The IEEE Standards Association's Industry Connection program, with its International Roadmap for Devices and Systems (IRDS), takes over the Semiconductor Industry Association's International Technology Roadmap for Semiconductors (ITRS).

FROM THE EDITOR

The IEEE, through the Standards Association, provides the Computer Society with support for not only pure standardization projects but also a framework for lighter weight industry collaboration. For many years, the Semiconductor Industry Association provided a home for the International Technology Roadmap for Semiconductors (ITRS) but in 2015, this work moved to IEEE. In this article, Tom Conte and I describe the work of the IEEE International Roadmap for Devices and Systems (IDRS). *—F.D. Wright*

Since the 1990s, the Semiconductor Industry Association has been periodically releasing its perspective on the evolution of semiconductors. This roadmap, International Technology Roadmap for Semiconductors (ITRS), has provided designers and manufacturers with a glimpse of the technical trends in the field likely to occur in the years after the roadmap is revised. While no roadmap is perfect, thinking broadly about how technologies are advancing and the implications of those advances is always a helpful exercise.

ITRS BECOMES IRDS

In 2015, the International Technology Roadmap for Semiconductors 2.0 signed an MOU with the IEEE Rebooting Computing Initiative after both parties realized they were seeking to achieve the same goals, namely rethinking how semiconductor devices need to respond to the needs of emerging applications and systems. The IEEE International Roadmap for Devices and Systems (IRDS) came from the ITRS 2.0 team and migrated

0018-9162/18/$33.00 © 2018 IEEE

from the Semiconductor Industry Association to IEEE in 2016. The new name, IRDS, reflects an expanded focus on applications and systems that drive the need for semiconductor devices. The IEEE Rebooting Computing Initiative, charged with rethinking all aspects of the computer from device to user interface, sponsored the work's transition to the Standards Association's Industry Connections Program (http://standards.ieee.org/develop/indconn). The Industry Connections Program describes itself as:

> *The IEEE Standards Association (IEEE-SA) Industry Connections (IC) program helps incubate new standards and related products and services by facilitating collaboration among organizations and individuals as they hone and refine their thinking on rapidly changing technologies. The IC program offers an efficient, economical environment for building consensus and producing shared results. Industry Connections empowers groups with a customizable menu of IEEE and IEEE-SA resources to produce "fast-track" content and deliverables.*

IRDS ORGANIZATION

The International Roadmap Committee (IRC) is the IRDS executive committee, and it is comprised of leaders from five regions of the world: Europe, Korea, Japan, Taiwan, and the US. These voting members are from NEREID (NanoElectronics Roadmap for Europe: Identification and Dissemination), SDRJ (The System Device Roadmap Committee of Japan), and three IEEE Societies (Computer Society, Electronic Devices Society, and Communications Society). Additionally, the IEEE Electronics Packaging Society (EPS) was recently invited to join. Every year a chair and vice chair are elected. IEEE Fellow, Paolo Gargini, currently serves as chair, while IEEE Fellow (and coauthor), Tom Conte, serves as vice chair. Gargini has been involved with the semiconductor roadmap since its inception in the 1990s.

While the Computer Society, Communications Society, and Electronic Devices Society, and others are active in the work of developing the IRDS, the team is open to members of all IEEE Societies.

ROADMAP STRUCTURE

The overall roadmap is divided into International Focus Roadmap Teams (IFTs), the chairs of which are selected by the IRC every year. These teams construct a horizontal roadmap for a given technology level, and the overall structure is shown in Figure 1. Current IFTs are:

- Application Benchmarking (AB),
- System and Architecture (SA),
- Outside System Connectivity (OSC),
- More Moore (MM),
- Beyond CMOS (BC),
- Packaging Integration (PI),
- Factory Integration (FI),
- Lithography (L),
- Metrology (M),
- Emerging Research Materials (ERM),
- Environment, Health, Safety, and Sustainability (EHS/S), and
- Yield Enhancement (YE).

The IFTs each work through consensus on their specific areas known as "roadmap chapters." Each of the IFTs assesses present status and future evolution of the ecosystem in their specific field of expertise and will then produce a 15-year roadmap. This includes evolution, key challenges, major roadblocks, and possible solutions. The integration of all the IFTs roadmaps will produce a "big picture overview."

The chapters are delivered to the IRC for review and comment and often return to the IFT multiple times through this iterative process. Once the chapter is fully approved by the IFT, it enters the roadmap for that year's edition.

In this way, the complete IRDS will

- identify the technology needs and the key enablers, potential solutions, and areas of innovation in order to resolve challenges and meet the 15-year targets for the industries enabled by the IRDS; and
- identify any potential cooperation with organizations interested to demonstrating possible solutions.

Note that the roadmap is published in odd-numbered years and updated in

FURTHER READING

More information about the work of the IRDS team can be found in the IRDS Industry Connections Activity Initiation Document on the IEEE Standards Association website (http://standards.ieee.org/about/sasb/iccom/IC16-006-02_International_Roadmap_for_Devices_and_Systems.pdf) and on the IRDS homepage (https://irds.ieee.org). The 2017 Roadmap is available at: https://irds.ieee.org/roadmap-2017.

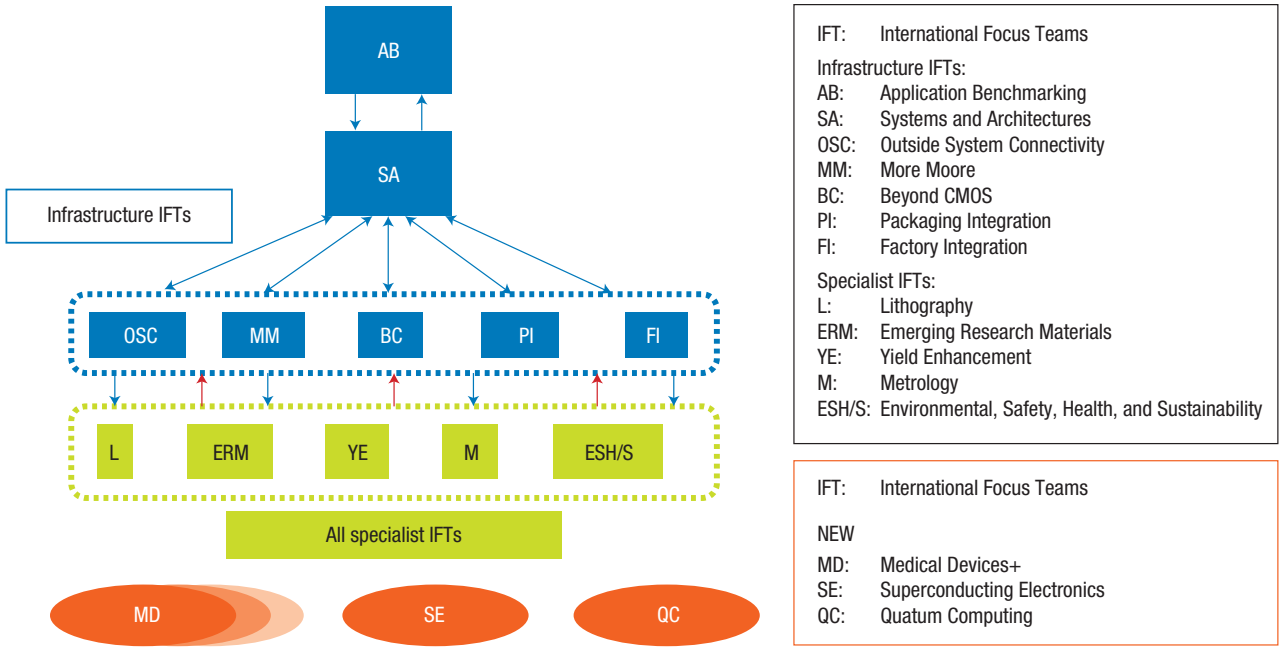

Figure 1. The International Roadmap Committee (IRC) organization. The infrastructure International Focus Teams (IFTs), including Application Benchmarking (AB) and System and Architecture (SA), are shown in blue; the specialist IFTs are shown in green. The new IFTs are shown in orange.

even-numbered years. Thus, the first edition of the IRDS under IEEE SA auspices was the 2017 edition. This year, the IFTs and the IRC are working to assemble an update. The next roadmap edition will then begin in 2019.

2017 EDITION OF THE ROADMAP

Compared to the ITRS, the IRDS takes a broader perspective on technology. By its name, the ITRS was almost exclusively focused on semiconductor technology. The new roadmap, the IRDS, takes a broader view by including system aspects in its work. Instead of just focusing on trends that enable building faster, smaller, and cheaper devices, hoping that companies will find applications and devices that can use them, IRDS also looks at the current and emerging applications and equipment, how people use them, and then projects the requirements for the semiconductors and chips that will go into them.

In April of this year, the 2017 version of the roadmap was published. An executive summary and 10 of the chapters were made available. (The "Packaging Integration" chapter was not yet available as of the writing of this column.) In addition, a white paper on "Virtual Metrology" and a "Medical Devices Market Driver" document were also published.

The 2017 edition considered a number of technology, industry, and market factors and their ecosystems that have significantly influence the roadmap, as shown in Figure 2. These include:

- Moore's law
- The Computer Industry
- SOC and SIP
- The Power Challenge
- The Consequences of Frequency Limitations
- The Internet of Things, Internet of Everything (IoT, IoE)
- 5G and Beyond
- Data Centers
- Product Confluence and Technology Fusion

KEY OBSERVATIONS

The 2017 Roadmap, and associated white papers and market drivers, includes over 400 pages of text, charts and graphs, offering a consensus view of the collective wisdom of semiconductor and related technologists from around the world.

Some observations from the 2017 Roadmap include the following.

- Application performance is proportional to memory bandwidth for all of the application areas tracked by the roadmap. However, memory latency is critical for some but not all application areas. Specifically, it's critical for big data analytics, optimization, and both physical and discrete event simulation.
- For other application areas, such as feature recognition, graphics, virtual reality, and augmented reality, fixed-function accelerators are critical. These areas will be heavily influenced by the technological improvements of logic.
- Internet of things edge devices (such as a smart thermostat)

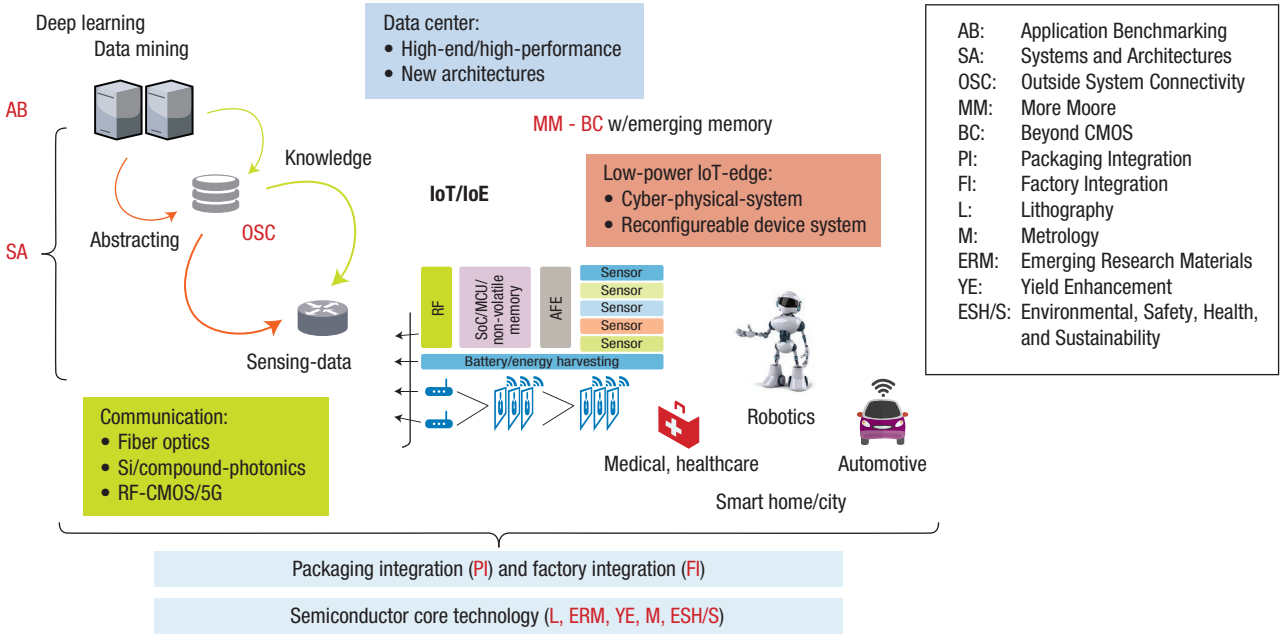

Figure 2. Graphic summarization of the Roadmap's executive summary.

will begin to include Artificial Intelligence (AI) algorithms as much as cost and power constraints allow. Despite advances, critical challenges remain on the horizon. Edge devices must be secure, safe, and protective of user privacy.

- Clouds and servers face challenges of power as well as I/O performance. It is predicted that I/O speeds will grow to match the internal network-on-chip speeds over time.
- Moore's law will continue into monolithic 3D with 3D transistors. Note that this is different from stacking multiple dies one on top of another. The 3D structures will be manufactured. No stacking will be required. Flash memory is already being produced this way. This switch to monolithic is predicted to happen in 2024.
- Physical gate length will level off at 12 nm in 2027. Meanwhile, power, which is proportional to the square of the operating voltage (VDD), will not decrease significantly. Today it stands at 0.75V. It is predicted to drop by only 0.2V by 2033. This will cause frequency to stagnate.
- DRAM technology will continue to produce denser memories, but a slowdown is predicted in 2030 at 32 gigabits per device. Flash memory, however, will continue to grow and reach four terabytes by 2033.

For better or worse, the coupling of Moore's law with Dennard scaling (also known as MOSFET scaling),[1] meant that computer performance was directly tied to transistor size. That coupling began to abrade in the 1990s and was fully decoupled in the 2000s. What it means today is that Moore's law will continue, and the number of transistors per die will continue to become exponentially cheaper with time. However, computer performance scaling is in crisis. The IRDS is tracking a changing industry that today is itself slowly embracing this application-driven, technology-focused future.

REFERENCE

1. Dennard, Robert H.; Gaensslen, Fritz; Yu, Hwa-Nien; Rideout, Leo; Bassous, Ernest; LeBlanc, Andre (October 1974). "Design of ion-implanted MOSFET's with very small physical dimensions" (PDF). IEEE Journal of Solid State Circuits. SC–9 (5).

F.D. WRIGHT is president of Standards Strategies, LLC, and the IEEE Standards Association. He is a member of the IEEE Computer Society, the IEEE Society on the Social Implications of Technology, and several others. Contact him at f.wright@ieee.org.

THOMAS M. CONTE is an IEEE Fellow and a professor of computer science and ECE at Georgia Tech. He served as president of the Computer Society in 2015. Conte is also a co-chair of the Rebooting Computing Initiative, and vice chair of the IRDS effort. Contact him at tom@conte.us.