Computing Community Consortium's Response to RFI "Manufacturing USA Semiconductor Institutes"

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This response is from the Computing Research Association (CRA)'s Computing Community Consortium (CCC). CRA is an association of nearly 250 North American computing research organizations, both academic and industrial, and partners from the professional societies. The mission of the CCC is to enable the pursuit of innovative, high-impact computing research that aligns with pressing national and global challenges.

The Covid-19 pandemic, in conjunction with a number of environmental factors, has exposed the weaknesses of the global semiconductor manufacturing process and supply chain. It is critical that the United States allocate funding and resources to increased domestic chip production, in order to alleviate the strain on existing semiconductor manufacturing facilities worldwide, and to decrease our country's dependence on foreign providers. The Computing Community Consortium would like to thank the National Institute of Standards and Technology for considering our input on this issue, and we offer our recommendations below (questions from the RFI are in bold and italics, with related commentary below.)

Chip-package architectures and co-design of integrated circuits and advanced packaging. May include artificial intelligence, security, test methodologies, etc.

The use of Artificial Intelligence in advanced packaging and co-design has great potential to reduce costs and speed time to market for chiplets, heterogeneous integration, and other advanced architectures. AI will mitigate many of the drawbacks of advanced architectures, including testing, heat dissipation, yield, and scaling. AI-driven reduced-order models of physical systems can replace and augment the physics-based models and numerical simulation used in parameter solving, identifying defects, and optimization. This will help designers converge on solutions faster and more cost effectively.

Realizing the potential of AI for advanced packaging will require a coordinated research effort across industry and academia. Fundamental challenges include building AI models accurate enough to be used as digital twins for physical systems and making manufacturing tolerant of increased uncertainty in models. They also include verifying the correctness and security of AI-produced packages with interpretable AI and building the verified data sets needed to train models. A broad research effort across academia, industry, consortia, and national labs will play a critical role in building the shared AI models and data sets that can be trusted to be accurate and secure.

Coding and system software with novel computing paradigms and architectures, including chiplet compatibility with earlier generations.

Chiplit technology is a promising area that must be developed with a full understanding of the emerging novel computing proposals and computing application needs. Specific novel computing paradigms and applications that can be identified today include unstructured on-line machine learning, optimization solvers, quantum computing control processors, large and dynamic graph processing, and highly-efficient sparse linear algebra calculations. System architectures for these require or can be enhanced by domain-specific accelerators, including analog and mixed-mode accelerators, near-memory / in-memory computation and cryogenic capable computing devices. With respect to analog and mixed-mode computation, a promising area is the leveraging of open-system thermodynamics to perform computational tasks[1]. This area is illustrative of others in the list: it has great potential but advancement is blocked because current CMOS-process-based semiconductor devices are ill suited to its computational model.

[1] Conte, Tom; DeBenedictis, Erik; Ganesh, Natesh; Hylton, Todd; Still, Susanne; Strachan, John Paul, Williams, R. Stanley. Computing Community Consortium, 2019, *Thermodynamic Computing*, https://cra.org/ccc/wp-content/uploads/sites/2/2019/10/CCC-Thermodynamic-Computing-Reportv3.pdf. Accessed 21 Nov. 2022.

We believe that a Manufacturing USA semiconductor institute should include a strong computing application focus and we are not alone in the observation that computing applications should drive semiconductor device priorities. Since the slowing of Moore's Law, there have been several efforts in restarting the historic exponential growth of computing power. The IEEE Rebooting Computing Initiative (RCI)[2] summarized these efforts in a set of levels of disruption of the computing stack. The IEEE subsumed the International Technology Roadmap on Semiconductors when the Semiconductor Industry Association suspended its sponsorship of it. After the ITRS was brought into IEEE, the leaders of the roadmap revamped it to focus on the RCI recommendations and renamed the roadmap the *International Roadmap on Devices and Systems*[3], the first edition having been written in 2016. Thus, the "top level" of the roadmap is now a task force (*International Focus Team*, i.e., the chapter author team) called the *Application Benchmarking IFT.* Application areas include AI, physical system simulation, Internet of Things security, large graph processing (as used in large data analytics), etc. The results of the AB IFT's work is used by a Systems Architecture IFT to predict computer architectures moving forward. Other focus teams in the roadmap, such as the Packaging IFT that tracks advances including chiplet technology, use these predictions to inform which semiconductor technologies will be critical and which semiconductor technologies will be less important.

Following the IRDS model, a Manufacturing USA semiconductor institute should include active research focus on computing applications and on novel system architectures. These researchers, both internal to and externally funded by the Manufacturing USA semiconductor institute, will ensure that the institute is a leader internationally in semiconductor development. This in turn will enable the US semiconductor industry to lead rather than "closely follow" the world semiconductor industry.

Environmental Sustainability for semiconductor manufacturing.

We believe that a Manufacturing USA semiconductor institute should include sustainability as a first class and cross-cutting consideration in its research agenda. The overall manufacturing

[2] Conte, Thomas M.; Debenedictis, Erik P.; Gargini, Paolo A.; Track, Elie. "Rebooting Computing: The Road Ahead." *Computer*, vol. 50, no. 1, 2017, pp. 20–29., https://doi.org/10.1109/mc.2017.8.
[3]"The International Roadmap for Devices and Systems." *The Institute for Electrical and Electronics Engineers (IEEE)*, 2022, irds.ieee.org/images/files/pdf/2022/2022IRDS_ES.pdf.

ecosystem, including semiconductor manufacturing, is resource intensive, and managing resources sustainably and reducing and disposing of waste is an important goal. Computing research and innovations in AI, robotics, algorithms, novel architectures, hardware and software, have a significant role to play in building sustainable ecosystems (see for example, CCC Report on Computing Research for the Climate Crisis[4]). A multi-disciplinary research agenda including socio-technical factors may provide effective sustainable manufacturing practices.

16. How could a Manufacturing USA semiconductor institute best support advanced manufacturing workforce development and/or awareness at all educational levels (e.g., for K-12 through post-graduate students)?

We believe that a Manufacturing USA semiconductor institute should conduct its education and workforce development in close partnership with both industry and academia. There are good lessons to be learned on effective collaboration models between academia and industry in the AI/ML revolution of the last few years (see CCC Report on Evolving Academia/Industry Relations in Computing Research[5]). In educating a new generation of students, Manufacturing USA semiconductor institutes could broker industry internships and access to industry labs, and facilitate the sharing of expertise across industry and academia through faculty sabbaticals and joint appointments.

Curricular guidelines should be developed that encourage early and ongoing interest in and an understanding of semiconductors and computer architecture, beginning in K-12 and extending through graduate courses and professional programs. Capability gaps specific to the semiconductor workforce include:

- K-12 education currently lacks a focus on digital design, computer architecture, and computer system fundamentals. Exposing students to the topics would create the

[4] Bliss, Nadya, et al. "Computing Research for the Climate Crisis." *Computing Community Consortium*, 1 Aug. 2021, cra.org/ccc/wp-content/uploads/sites/2/2021/08/Computing-Research-and-Climate-Change-%E2%80%94-August-2021.pdf.
[5] Patel, Shwetak, et al. "Evolving Academia/Industry Relations in Computing Research." *Computing Community Consortium*, 1 Jun. 2019, cra.org/ccc/wp-content/uploads/sites/2/2019/06/Evolving-AcademiaIndustry-Relations-in-Computing-Research.pdf.

excitement needed to direct them toward further education and careers in the semiconductor field.

- We need to train highly-skilled engineers and technicians and we need to dramatically grow the workforce to support Manufacturing USA. Industry and academia must partner with community colleges, workforce retraining programs, certificate programs, and online degrees to create onramps to the semiconductor industry.
- Curriculum needs to address the ethical and policy aspects of semiconductor manufacturing, including material supply chains, energy consumption, and their effects on climate and society.
- We need to engage underrepresented and underprivileged groups in order to bring the best talent into the Manufacturing USA effort.

Thank you very much for this opportunity to share our input on the development of the Manufacturing USA semiconductor institutes. We hope our feedback will prove useful in the development of these institutes, and we will remain “at the ready” to answer future questions on this topic.