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Before the Committee on Science, Space, and Technology

"Ensuring American Leadership in Microelectronics"

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Chairwoman Johnson, Ranking Member Lucas, and members of the Committee, I am honored to appear before you to discuss the status of U.S. leadership in advanced semiconductor development and manufacturing, particularly as it relates to memory and storage technology. Chairwoman Johnson, please also allow me to congratulate you on your upcoming retirement and thank you for your decades of distinguished service. My thanks to you and to the members of this committee who are spearheading the bipartisan effort to ensure long-term U.S. leadership of critical semiconductor R&D and manufacturing capability. With your permission I will submit my full statement for the record.

I testify today as Executive Vice President of Global Operations at Micron – the world's memory and storage technology leader. Micron is the only company developing leading-edge memory and storage technology in the United States, and the only firm manufacturing DRAM or NAND in the United States. Headquartered in Boise, Idaho, Micron is the world's fourth largest semiconductor integrated device manufacturer and the second largest in the United States. We have 43,000 team members worldwide, with nearly 10,000 of them located in facilities across the United States, including in our Manassas, VA facility where we manufacture memory and storage solutions that are critical to driving growth in expanding automotive, industrial and networking markets.

I hope to leave you with two key takeaways:

- First: memory and storage technologies are essential to a digital and data-intensive future for the United States; and

- Second: long-term, substantial investment in leading-edge semiconductor R&D and manufacturing is vital for the United States to maintain technology leadership across diverse end applications from the cloud to the edge and everywhere in between. Memory and storage are foundational for every computing paradigm. Creating a meaningful domestic manufacturing base for memory and storage – through funding of incentive programs such as those included in the CHIPS for America Act and implementation of a refundable investment tax credit will enable a domestic supply of these essential devices.

The Critical Role of Memory and Storage

Micron designs, develops and manufactures industry-leading semiconductor memory and storage products – the most common of which are DRAM and NAND. These products are critical to all sectors of the U.S. economy and national security. By providing foundational capability for AI and 5G across data center, the intelligent edge and consumer devices, Micron's products unlock innovation across industries including healthcare, automotive and communications. Computing workloads of the future are increasingly data intensive, requiring highly reliable, high performing and power efficient advanced memory and storage solutions to optimize results.

Memory and storage have grown from 10% of the global semiconductor industry revenue in the year 2000 to about 30% of the semiconductor industry today. We expect this trend to continue. For example, 5G phones have 50% more memory (DRAM) and double the storage (NAND) content as compared to 4G

phones. Autonomous vehicles of the future will require as much DRAM and NAND storage as today's servers, as cars become data centers on wheels. Conversely, domestic manufacturing has experienced a steady decline. For example, in 1990, the U.S. had 37% of global chip manufacturing capacity and now only accounts for 12% (and only 2% of global memory production).

We believe Congress should focus on three key areas when considering the conditions under which long-term U.S. leadership of these critical semiconductor technologies can flourish: research and development, manufacturing, and workforce development.

Investment in Research and Development

Micron has developed and is producing the world's most advanced nodes of DRAM technology – 1 alpha – as well as the most advanced NAND technology – 176 layer. Our technology leadership is based on an unwavering commitment to innovation in both R&D, with our aggressive technology roadmap, and manufacturing, where we deliver these industry-leading technologies at scale.

Micron invests substantially in research and development. In our fiscal year 2021, R&D spending was nearly $3 billion and we plan to increase that by about 15% in 2022. We have consistently expanded our Technology Innovation Center of Excellence in Boise, Idaho over the past decade. We're also proud to partner with the Departments of Energy and Defense, as well as the National Science Foundation, on leading-edge research initiatives that will further drive technology leadership and fuel technologies of the future

The results of this commitment to innovation are clear; Micron is responsible for nearly 50,000 patents and counting, deploys new technology innovations and associated products at least every two years, and currently produces the world's most advanced memory and storage solutions.

The U.S. government maintains and Micron supports a range of successful R&D programs designed to advance U.S. technology leadership. As it considers new investments in R&D, as with the National Semiconductor Technology Center, the United States should complement these existing programs by focusing needed resources on bridging the gap between the lab and production for new technologies.

Several challenges prevent foundational research undertaken at universities, labs, and start-ups from transitioning to commercialization. This gap widens as semiconductor technologies advance. The U.S. Government can promote successful commercialization by facilitating prototyping capabilities for new and innovative technologies. Micron recommends that the U.S. government fund research focused on advanced memory and storage technology including:

- *To enable AI and next generation cloud and communication capabilities*, investment in near-memory and in-memory compute advancements to achieve an order-of-magnitude improvement in performance for future high-performance systems.

- *To provide 10-fold energy efficiency gains,* investment in heterogeneous integration of memory and storage with data generation (sensor) and data processing (compute) through establishment of advanced prototyping infrastructure.

- *To enable new storage technologies and emerging memory fabrics with 10 to 100-fold density, performance, and energy efficiency,* investment in materials, architecture, simulation and advanced design methodology.

New, focused investment in semiconductor-related research will accelerate industry's own efforts and play a key role in industry's ability to maintain U.S. technological leadership.

Investment in Domestic Manufacturing

To continue to lead the world in innovation, the United States must also strengthen its domestic manufacturing capacity. A stronger domestic industrial base will both ensure a secure supply chain and accelerate domestic R&D. In doing so, it will also create highly skilled jobs and stronger communities.

Micron is proud to operate the only memory or storage manufacturing facility in the United States at our Manassas, Virginia facility. We are committed to investing in the future of memory and storage manufacturing, having pledged to invest more than $150 billion globally over the next decade in leading-edge memory manufacturing and R&D, including potential U.S. fab expansion.

Congress can take two immediate steps to set the conditions for long-term U.S. leadership in semiconductor manufacturing: fully fund The CHIPS for America Act and provide a refundable investment tax credit to give companies the confidence to invest in the U.S. semiconductor ecosystem and technology leadership for the long-term.

The United States should focus support toward leading-edge manufacturing capabilities to maximize the commercial success of the investments which will in turn fund future R&D innovation.

Investments must also take into account that memory and storage manufacturing must be made on a massive scale to be competitive, that operating costs in the United States are higher than in Asia, and that many foreign governments provide incentives to attract and sustain advanced manufacturing.

To be commercially viable over the long term, memory and storage fabs must produce at very high volumes. Multiple clean room facilities are required to achieve this scale, each costing more than $15B fully equipped.

Further, it costs 35% to 45% more to build and operate a fab at scale in the United States than in lower-cost markets. Additionally, there is significant investment in leading edge R&D that must be amortized at scale to recover the investment. The technology developed in R&D requires continuous improvement after it is transferred to manufacturing to improve process margin for yield, cost, manufacturability, and quality. These are all critical factors to scalability. In order to overcome these scale and operating cost challenges, CHIPS funding and a refundable investment tax credit are imperative to enable domestic memory manufacturing to expand.

Finally, U.S. government investment is required to keep pace with other governments' investments in their own industries, which reduce our competitors' operating costs. For example, South Korea has said it will invest more than $450 billion in the semiconductor industry by 2030. Reports suggest China is on track to invest more than $150 billion from 2014 through 2030.

Investment in a Qualified Workforce

The United States must also invest now to ensure it has the workforce it needs for the future. From a workforce perspective, the industry is already in crisis. The technical positions required by our industry range from process engineers, product engineers, chemists, fabrication engineers, test engineers, quality engineers, technical marketing and field engineers to fab technicians and operators. The majority of these highly-skilled technical positions require an advanced degree or backgrounds in electrical engineering, chemical engineering, mechanical engineering, materials science, physics, electronics, data science, cloud computing, automation, digital security and artificial intelligence and machine learning. Candidates with

these backgrounds are already highly employable and the shortage in these relevant skills has a tangible impact on our workforce.

Micron remains focused on developing our critical talent to focus on data analytics, smart manufacturing and emerging AI applications and related process improvements for the future. To build the workforce we need for our fab in Virginia and world-class research center in Boise, Micron partners closely with academic institutions at all levels—K-12, community colleges, and universities. We work with them to build curricula, provide internships and scholarships and the equipment and materials students need to prepare for work in today's industry, and help onboard them into long-term careers. We also partner with reskilling programs, including those focused on veterans, to transition high potential individuals into the industry.

We expect these shortages will continue — and these impacts will worsen — without a concerted, government-supported effort to improve STEM workforce availability and diversity at our U.S. universities and colleges. We will continue to strengthen these partnerships, but positioning the United States for continued expansion requires the focused attention of the federal government on strengthening the workforce. Congress should continue and expand funding to increase STEM education at all levels, enable the expansion of vocational programs at community colleges, promote re-skilling programs, and facilitate public-private partnerships to train and employ new entrants in the industry.

Conclusion

Memory and storage are essential elements of all technology solutions. With the recent unparalleled attention on the semiconductor industry and supply chain challenges, Congress is well-positioned to act. The United States must keep pace with the rate of technological change – and human innovation. I am proud that Micron is a pillar of the U.S. semiconductor industrial base, and we stand ready to work with this Committee and others in Congress and the Executive Branch to ensure the United States achieves and maintains the world's leading digital and data-intensive economy in the decades ahead.

Manish Bhatia

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Manish Bhatia is the executive vice president of Global Operations at Micron Technology. He is responsible for driving the vision and direction for Micron's end-to-end operations. Mr. Bhatia joined Micron in 2017.

Mr. Bhatia most recently served as the executive vice president of Silicon Operations at Western Digital Corporation. Prior to that, Mr. Bhatia held several executive roles at SanDisk Corporation and was the company's executive vice president of Worldwide Operations when it was acquired by Western Digital. Prior to SanDisk, Mr. Bhatia's career included positions at Matrix Semiconductor, McKinsey & Company and Saint Gobain Corporation.

Mr. Bhatia earned bachelor's and master's degrees in mechanical engineering from the Massachusetts Institute of Technology and a master's degree in business administration from MIT's Sloan School of Management, which he attended as a Leaders for Manufacturing fellow.