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USPAE
U.S. Partnership for Assured Electronics

Department of Commerce Request for Public Comment
"Risks in the Semiconductor Manufacturing and Advanced Packaging Supply Chain"
Docket #: BIS-2021-0011
Deadline: April 5, 2021
Submitted by: IPC and USPAE

On behalf of our more than 1,500 U.S. member companies in the electronics manufacturing industry, IPC and USPAE encourage robust federal support for the U.S. semiconductor supply chain, which necessarily extends to other key segments of the electronics industry. Advancements in semiconductor technology have always been intricately linked to advancements in printed circuit board (PCB) fabrication and assembly, but the interdependence is growing even greater with developments in microelectronics.

Our industry supports more than 5 million U.S. jobs and drives more than $700 billion in U.S. GDP. This includes all segments of electronics manufacturing, such as designers, PCB manufacturers, contract and assembly companies, suppliers, and original equipment manufacturers (OEMs) in aerospace, defense, medical, automotive, and other industrial sectors reliant on electronics.

The last 25 years have been a turbulent period for U.S. electronics manufacturers, marked by significant contraction and financial instability. Thousands of electronics manufacturers have closed their doors, and the number of U.S. PCB manufacturers and assemblers has ebbed. That said, the surviving electronics manufacturers and PCB fabricators are driving innovation in advanced packaging for integrated circuits (IC), and they are doing so with little to no government support and despite significant disadvantages in the global marketplace. The electronics industry, for more than 20 years, has urged U.S. policymakers to better reflect in policy and funding the strategic importance of the entire industrial ecosystem that supports U.S. leadership in semiconductors.

In this vein, we applaud President Biden for ordering this 100-day review of the semiconductor manufacturing and advanced packaging supply chain, and we welcome the opportunity to provide input to the Department of Commerce (DoC) as it works with peers across government to identify and address risks to this critically important domestic supply chain. However, IPC, USPAE and our members must reiterate that the U.S. Government must invest not only in semiconductor manufacturing, but also in the entire electronics ecosystem for the United States to maintain its technological leadership. We urge the Administration to take a holistic approach when considering risks associated with the electronics supply chain.

In response to the request for comment, we offer five main points:

- First, U.S. Government support of semiconductor manufacturing and advanced packaging is a vital U.S. strategic interest.
- Second, the assembly and printed circuit board industries are a critical part of the semiconductor supply chain.
- Third, U.S. electronics manufacturing has atrophied even as U.S. leadership in design has remained strong.
- Fourth, the United States has an important role to play in cultivating an environment in which electronics manufacturing can thrive.
- Finally, investments in electronics manufacturing broadly defined are essential to leveraging the significant investments the United States is making in the semiconductor industry.

I. U.S. Government support of semiconductor manufacturing and advanced packaging is a vital U.S. strategic interest.

Since World War II, the United States has been the leader in the development of the most innovative and cutting-edge technologies. But today other countries are applying significant resources to challenge the United States' dominance.

One area of U.S. leadership is semiconductors, which play a critical role in enabling the products and services that fuel our economy, contribute to American innovation, and enhance our national security. IPC and USPAE believe that strengthening semiconductor manufacturing and advanced packaging is critical to maintaining U.S. leadership in technology; and semiconductor research, design, and manufacturing should be a national priority. However, the United States must continue to strengthen its leadership not just in semiconductors, but in all areas of the electronics ecosystem; and it must do so by investing in research and development (R&D) and establishing a federal strategy for electronics manufacturing.

Electronics manufacturing is part of the foundation for the manufacturing sector across the U.S. economy. Virtually every other sector relies on electronics to a greater or lesser extent. Thus, the U.S. Government must understand that the electronics supply chain is an ecosystem with many parts. We support President Biden's proposal of $50 billion for the U.S. semiconductor industry, and we urge the administration to work with Congress to fully fund the Creating Helpful Incentives to Produce Semiconductors (CHIPS) for America Act in the FY2021 NDAA, which aims to build and modernize semiconductor manufacturing facilities in the United States. But again, semiconductor fabrication is just one critical sector in a sophisticated, global supply chain for electronics. All segments of the electronics industry must be strong for the entire ecosystem to thrive.

II. The assembly and printed circuit board industries are a critical part of the semiconductor supply chain.

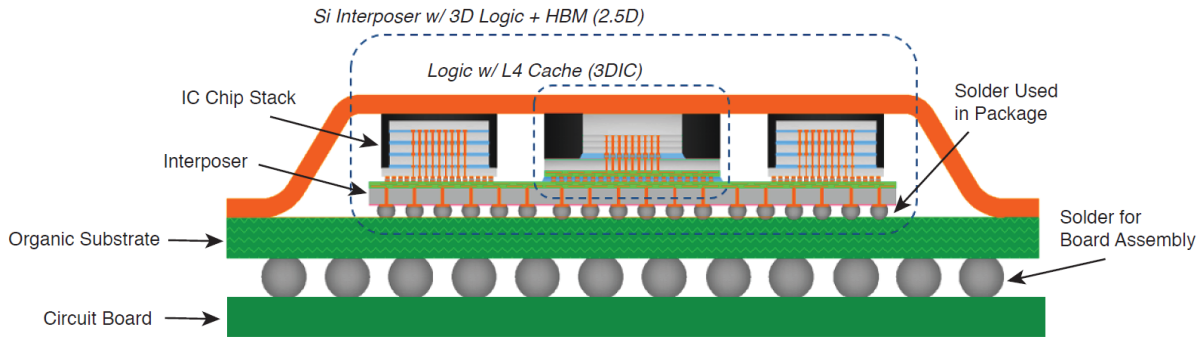
The electronics manufacturing industry is at the heart of the modern economy. It is a large, vertical industry in its own right, but it is also a horizontal industry that cuts across every sector of the economy. Electronics are critical in the performance of automobiles, aircraft, medical equipment, retail, industrial

operations, IT and telecom, consumer technologies, and more. And yet, government initiatives often focus on bolstering competitiveness in certain components, such as semiconductors, or verticals, such as automobiles, without appreciating that electronics manufacturing is an essential driver for innovation and growth across the economy.

Semiconductors are components that need to be placed on PCBs by assemblers. The more advanced the components, the more advanced the PCBs and assembly process. These advancements are forcing changes in PCB design and assembly as microelectronics push new boundaries with more computing power in more confined spaces. This includes heterogeneous integration through advanced packaging, in which multiple semiconductors are placed on substrates to form an advanced multichip module. These modules are then assembled on PCBs.

Substrates are like PCBs in construction and function in that they make connections from microelectronics-scale to PCB-scale circuitry. The same manufacturing concepts that apply to PCBs also applies to substrates. Advancements in additive processing technologies are enabling microelectronics to continue to shrink in scale as PCBs and substrates continue to become more advanced. Next-generation electronics systems are pushing the limits of what is possible by increasing complexity while reducing the size of semiconductors, substrates, and circuit boards. Without these advancements in PCBs and substrates, the power of microelectronics would be inaccessible for applications.

The following figure illustrates the complexity of manufacturing advanced electronics applications.



Source: Heterogeneous Integration Roadmap, Chapter 2 – https://eps.ieee.org/images/files/HIR_2019/HIR1_ch02_hpc.pdf

- **Silicon Interposer:** Multiple IC chips are manufactured and then assembled (or stacked) on a silicon interposer. The interposer connects silicon-scale circuitry to organic-substrate-scale circuitry. The silicon interposer may also interconnect the IC chips, hence the term heterogenous integration. The silicon interposer will be manufactured by the wafer fab.

- **Organic Substrate:** The connections on the silicon interposer are still too small to attach directly to the circuit board; therefore, an organic substrate is manufactured to scale circuitry from interposer-scale to PCB-scale. The organic substrate is like a PCB and utilizes many of the same manufacturing techniques. However, additive processes will be necessary to form the fine circuitry.

- **Organic Substrate Assembly:** Advanced manufactured techniques are required to align and place perfectly flat silicon interposers onto organic substrates.

- **Printed Circuit Board:** The fanout, the process of pathing circuitry from a highly concentrated location and fanning it out to all of the components, of organic substrates range in size, spacing, and density. The most advanced substrates may have upwards of 10,000 inputs and outputs concentrated into very little space. PCB manufacturers must be able to manufacture high-density interconnects to keep up with advancements in electronics. To do so, PCB manufacturers require access to skilled workers, capital equipment, and expertise.
- **PCB Assembly:** Finally, the organic substrate is assembled (attached) to the PCB. Not depicted in this illustration are the tens of thousands of other components that reach out into the real world, making the purpose of the electronic system possible.

Clearly defined in the illustration is the significance of the substrate and circuit board that makes the entire stack of electronics a unified system, from the IC chips to the end-user application. All these components are part of the microelectronics ecosystem.

III. U.S. electronics manufacturing has atrophied even as U.S. leadership in design has remained strong.

Prior to 2000, the United States was the world's leading electronics manufacturer. In the 20 years since, electronics manufacturing has largely moved to Asia. Asia now produces more than 70 percent of all electronics manufactured globally. The U.S. PCB industry, which once accounted for more than 30 percent of total global production, today accounts for less than 5 percent. Furthermore, all electronics and products with electronics in them are reliant upon electronics manufacturing services (EMS), but only four of the top 20 EMS companies are based in the United States.

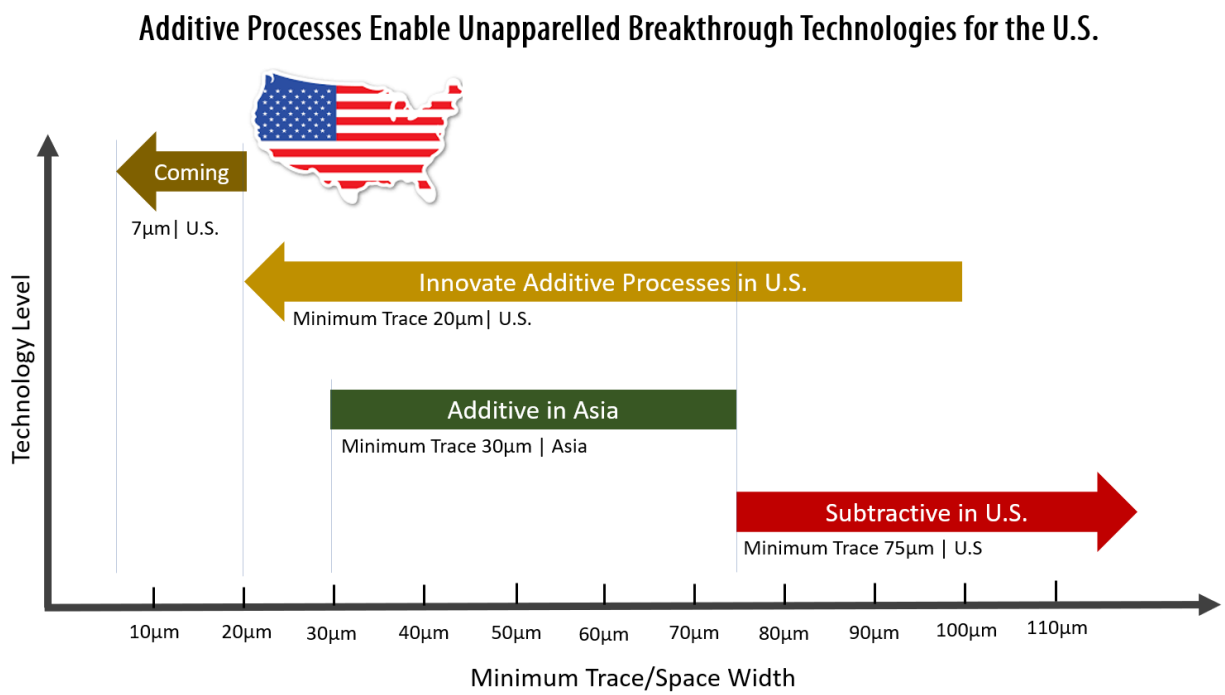
As microelectronics continue to advance at a breakneck pace, the gap between Asia and U.S. electronics manufacturing capability continues to widen. We estimate the United States is 20 years behind Asia in PCB manufacturing technologies necessary for next-generation electronics applications and 30 years behind in the capability to manufacture the PCB-like substrates necessary for advanced microelectronics packaging. U.S. defense and commercial OEMs are urgently developing next-generation heterogenous multichip packages for state-of-the-art- electronics systems, sourcing the complex PCB and IC substrates, from predominately Taiwan, South Korea, Japan, and China. A clear strategic need exists to source not only complex PCBs, but also microelectronics substrates from U.S. manufacturers.

In 2015, the Department of Defense (DoD) Executive Agent for Printed Circuit Board and Interconnect Technology executed through the DoC a mandatory survey of the U.S. PCB industrial base. In 2018, the DoC Bureau of Industry and Security delivered its findings, characterizing the U.S. PCB industry as "dying on the vine." The September 2018 report by the Interagency Task Force in Fulfillment of Executive Order 13806 reported, "the U.S. printed circuit board sub-sector is aging, constricting, and failing to maintain the state-of-the-art" technology.

A once thriving $10 billion industry was reduced by 80% between 2001 and 2015. In the late 1990s, more than 2,000 circuit board manufacturers were in operation, whereas there are less than 145 PCB suppliers remaining today, and the number is even fewer when counting only suppliers with domestic manufacturing capability, as opposed to brokers.

The decimation of the once proud U.S. PCB industry represents not only a contraction of production capacity in the United States, but an egregious loss of manufacturing capability, leaving the United States with an inability to manufacture very complex technologies, even at low volumes. Furthermore, this shift has compromised the resilience, security, and competitiveness of the U.S. electronics industrial base. Among other negative impacts, the loss of U.S. electronics manufacturing is detrimental to military capabilities and readiness, creating unnecessary risks to U.S. national security.

The ability to manufacture fine copper circuits is of paramount importance. Where subtractive processes in the United States have been limited to 75µm for decades, the semi-additive technologies in Asia are achieving 30µm (e.g., the Apple iPhone) at high volume. The commercialization of advanced additive technologies for forming circuits on PCBs and substrates will allow U.S. PCB manufacturers a reliable low-cost solution to manufacturing 25µm to 7µm copper features. Rapid commercialization of additive technologies will enable electronics with higher density (36x), reduced size, reduced weight, and increased reliability. When combined with advanced materials and substrates, this technology provides improved signal integrity, higher frequencies and speeds, and higher thermal dissipation.

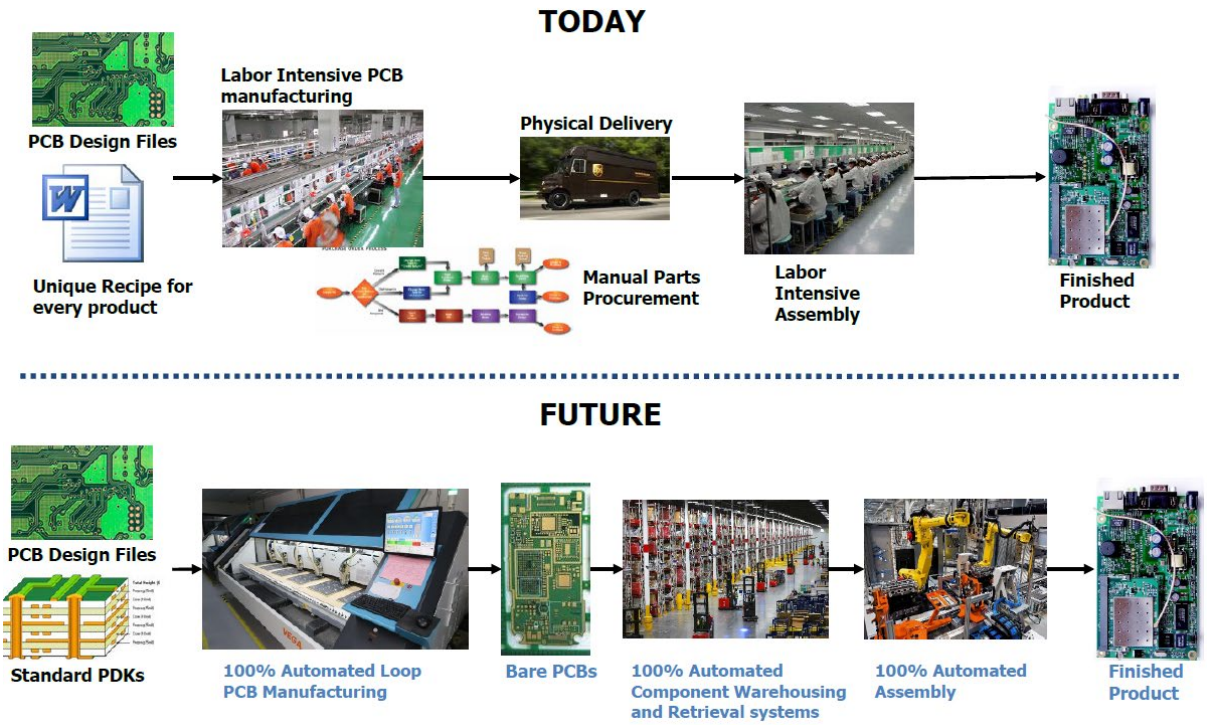


IV. The United States has an important role to play in cultivating an environment in which electronics manufacturing can thrive.

Electronics manufacturing is on the cusp of tremendous change, driven by technological advancements in artificial intelligence, automation, and machine-to-machine communications. The factories of the future can be the basis for a manufacturing resurgence in the United States, creating new opportunities for a skilled workforce. The United States should develop a strategy to support the industry's migration to factories of the future. U.S. manufacturing competitiveness over the next 25 years and beyond

depends upon U.S. companies operating more efficiently and intelligently to produce the increasingly sophisticated electronics-based systems of the future.

Electronics manufacturing is a thin-margin business, making it difficult to upgrade costly manufacturing equipment. And yet, such upgrades will be necessary to perform the sophisticated work expected of U.S. manufacturers by their customers, including the DoD. These equipment upgrades are also imperative to achieving the capabilities, quality standards, and cost-efficiencies necessary to compete in the global economy. It will take significant investment in equipment and "know-how" to stand up factories that can compete with Asian PCB manufacturers.



Source: IPC, BCC Research (Future of PCB production shared at DARPA Intelligent Manufacturing and Assembly (IMA Workshop) Dec. 2018)

According to the DoD Executive Agent (EA) for Printed Circuit Board and Interconnect Technology, PCBs and printed circuit board assemblies (PCBAs) are critical features of national defense systems and although "the global industry for electronics is growing at a rapid pace and making huge leaps in technological advancement every year, the domestic [PCB] industrial base continues to decline." The EA identified several supply chain risks associated with domestic and global PCB production, including:

- "The trustworthiness of [PCB] and [PCBA] manufacturers for national defense systems is inconsistent and weakly enforced. National defense systems using electronics, including all products on the United States Munitions List, are vulnerable to tampering with malicious intent, supply chain disruptions, counterfeit parts and materials, physical and cyber security, and substandard quality and product assurance."
- "The United States is chronically behind the state-of-the-art in [PCB] and [PCBA] manufacturing. Multiple factors contribute to the delay in adopting advanced and innovative technology, such as reduced market share and profitability due to offshore competition."

V. Investments in electronics manufacturing broadly defined are essential to leveraging the significant investments the United States is making in the semiconductor industry.

The U.S. Government has long underestimated the strategic significance of electronics manufacturing within the United States and continues to do so even with the clear indicators of alarming risk to the country, undermining the sustainability, resiliency, competitiveness, and security of the U.S. electronics supply chain. The realization of all electronic systems, from a simple wall clock to the flight controls in the F35 fighter, requires custom PCBs that are designed, manufactured, and assembled to accomplish the mission. Without the advanced interconnection technologies present in PCBs and IC substrates, advanced microelectronics components such as semiconductors would not function.

Sophisticated cyberattacks on critical U.S. supply chains are increasingly frequent, aggressive, and successful. As the potential for software infiltration, intellectual property theft, component counterfeiting, and hardware tampering compromises the security of electronics systems manufactured offshore, OEMs interested in or required to reduce risk by reshoring manufacturing of critical technologies are seemingly astonished to discover the domestic PCB manufacturing industrial base offers limited capability and capacity.

Furthermore, with essentially zero capability for advanced microelectronics packaging substrates, DoD's prime OEMs are faced with the choice of simplifying their most advanced and sensitive electronic system designs to be manufacturable domestically or face security and stability risk sourcing from Asian PCB and substrate manufactures. This is not a formula for the United States to gain or sustain supremacy in electronic systems; rather, it puts the United States at significant risk and disadvantage.

Policy Recommendations

- We encourage robust investments in Defense Production Act Title III funds to support industry modernization. Likewise, the Department of Commerce should explore funding mechanisms to support capital equipment upgrades through federal subsidies, no-interest loans, and tax credits. Commerce Department authorities have never been fully leveraged to support an ambitious U.S. manufacturing strategy.
- A robust manufacturing strategy requires a more localized ecosystem for raw materials, components, and parts. The United States has allowed much of the supply chain to go offshore, making U.S. manufacturing less nimble. We urge the administration to recognize that the electronics supply chain is an ecosystem, and all segments of the industry must be strong for the entire ecosystem to thrive. Praiseworthy investments in one segment, such as semiconductor manufacturing, also require investments in other segments of the industry.
- One of the most difficult challenges facing today's electronics industry is a chronic shortage of adequately skilled workers. More than two-thirds of IPC's U.S. members report that an inability to find and retain skilled workers is limiting their growth and competitiveness. Part of this challenge is due to the rapid rate at which technology evolves. To align job training with job growth, we urge support for industry-recognized credentials through:
    - Business tax credits for expenditures on training and certification offered by industry associations.

- Tax incentives for training and certification at the individual level, focused on post-secondary education expenditures.
- Grants for industry-based organizations to help cover costs of industry training program development and upskilling workers who may be displaced due to automation.
- Partnering with trade associations to identify critical training and certification programs in key industries and ensure that federal contracting requirements contain language supporting these programs, which would increase workforce quality and reliability while ensuring workers are ready for the technological challenges of tomorrow.
- Federal funding for trade associations to develop "next-gen" or "future-facing" training programs to keep U.S. electronics manufacturing competitive.

- We encourage federal support of "trusted supplier" programs in domestic and international supply chains for critical sectors of national security, as there is a need for greater supply chain visibility and transparency. Additionally, we recommend establishing metrics for defense electronics industrial base resiliency, with capacity, capabilities, security, and geographic diversity as key factors.
- We urge the administration to explore development of and access to rare earth minerals, as well as new initiatives for the production of raw materials critical to electronics manufacturing. The most sophisticated manufacturing capabilities cannot be leveraged without the parts and materials necessary to their operations.
- Industry funds for R&D are constrained by the industry's thin profit margins. Companies in Asia and Europe—with the support of national governments—are undertaking research that will enable them to lead the world in PCB fabrication and assembly. Meanwhile, in the United States, the focus is almost singularly on one or two segments of the electronics industry to the exclusion of others. For example, the United States is rightly investing billions of dollars in microelectronics and semiconductors, but those sectors and others would also benefit from sizable investments in PCB fabrication and assembly. The DoD should undertake a specific initiative to study and pursue research on the areas of PCB fabrication and assembly that are necessary to support advancements in microelectronics.
- The Tax Cuts and Jobs Act (TCJA) is changing the treatment of R&D tax costs. Currently, companies can fully deduct R&D costs from taxable income in the year that those costs occur, but starting in 2022, companies will be required to amortize their R&D costs over five years. We support maintaining full expensing to avoid discouraging investment and economic growth.

The failure of the United States to appreciate the strategic significance of electronics manufacturing has undermined the resiliency, competitiveness, and security of the U.S. electronics supply chain. Competing globally in the years ahead will require the U.S. Government to adopt a more holistic approach to measuring the health of the electronics manufacturing ecosystem and appreciating the strong connection between the semiconductor supply chain and the wider PCB and assembly industries.