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INTERN REPORT

Assembly Metrology Intern

Abstract

This report is a written assignment by Firas Hilman Bin Harizan for his internship at Micron as an Assembly Metrology Intern from 11 March to 8 August.
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1. Introduction

During my 3rd Year, 1st Semester in Singapore Polytechnic studying the Diploma in Engineering with Business, I started my internship module from 11 March to 8 August 2024. I was hired by Micron Semiconductor Asia Pte Ltd under the Assembly Metrology department.

Micron Semiconductor Asia Pte Ltd, better known as Micron Technology, Inc., is a leading multi-national corporation and manufacturer of semiconductor products such as computer memory, data storage, dynamic random-access memory, flash memory and USB flash drives.

In Singapore, Micron fabricates their wafers, substrates, and other components in their factories. After fabrication, these components will be transported to the back-end assembly line in MSB Singapore which is the location I am working and doing a project on.

Here at MSB, the wafers, substrates and other components will undergo a stringent process of assembly in a cleanroom which is one thousand times cleaner than a surgical theatre. Throughout the assembly process, the metrology department conducts data extractions for measurements and inspections daily/weekly for data analysis.

For my internship project, I will be focusing on the Flip Chip Process within the assembly line. The flip chip is a controlled collapse chip connection method for connecting the IC chip to the external circuitry or substrate through the prefabricated solder bumps during production. During assembly, these flip chips will undergo several additional processes. This invites many plausible causes of failure or rejects, reducing the yield of production of the DRAM.

Flip chip is a controlled-collapse chip connection, an advanced semiconductor packaging technique utilizing Copper pillars for direct connection with the PCB strip. This allows for much quicker connectivity, miniaturization of components. Flip Chip acts a Managed NAND controller, essentially like a library, managing data stored on flash memory and communicate with the electronic device.

With the rising demand for the flip chip controller die in memory solutions, it has become essential to create automated processes to conduct quality analysis to deliver innovative products to our clients, aligning with Micron’s mission in becoming a global leader in memory and storage solutions.

2. Business Analysis

2.1. Company Background

Founded in 1978, Micron started off as a four-person semiconductor design company in Boise. The company's first contract was for its design of a 64K memory chip for the Mostek Corporation which ended up being the smallest 64K DRAM design in the world. After the groundbreaking of their first fabrication site, Micron continuously created newer and better DRAM chips for the market.

In 1999, Micron created the industry’s first ever Double Data Rate DRAM which could deliver a performance to its predecessor DRAM at a much lower cost. To this date, DDR has become the industry standard for high performance DRAM.

Micron has gained global reach in terms of market share through worldwide manufacturing facilities and research centers. Additionally, Micron acquisition of Texas Instruments memory department in 19998 and Elpida Memory in 2013 has boosted the company to become one of the top three manufacturers of DRAM. (Micron, 2024)

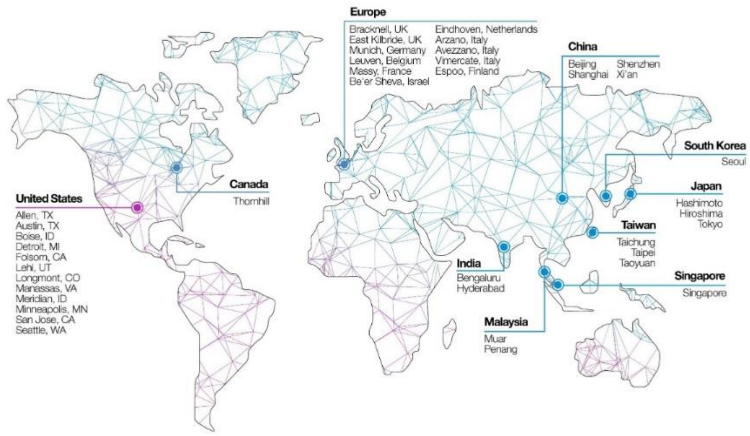
Micron is a leader in the design and manufacturing of innovative memory solutions ranging from DRAM components and modules, SSD data center and storage, Managed NAND, NAND, and NOR. With a core focus in memory and storage solutions, Micron addresses the business market in several industries, from the automotive driverless car to the up and booming AI market.

2.2. Company Statistics

Micron is a global company with around 44,000 team members globally. As of 2023, Micron is the fifth largest semiconductor company in the world with over 53,000 patents. With an annual revenue of $USD 30.8B in FY2022, Micron is 136 on the 2023 Fortune 500, which consist of the top five hundred corporation in the United States by total revenue for the respective fiscal year.

Micron has gained a global presence in the industry of memory manufacturing over the years. Currently, Micron has presence in seventeen different countries with fifteen customer labs and eleven manufacturing sites in countries with a highly skilled workforce. (Refer to Figure 1) Additionally, Singapore has Micron’s largest manufacturing footprint with a total of three fabrications facilities, FAB10W, FAB10N, and FAB10X and a test and assembly facility, MSB. Locally, Micron employs a sizable portion of our workforce reaching about 9,000 employees. (Choo Yun Ting, 2021)

Map of Micron Technology Operations Locations



Micron's Global Footprint (Micron, 2022)

In 2023, Micron faced a significant net loss of 2023 reaching $USD 5.3B due to a downturn in the semiconductor industry, specifically in the memory segment. Weaker demand in electronic consumer goods led to a decline in production hence resulted in the DRAM and NAND products to face lower revenue for the fiscal year. (Statista, 2023)

Despite the lower returns, Micron Tehcnology Stock MU: had a strong bullish performance in the year 2023. On 1 January, the stock was trading at a high of 63.896 and a low of 49.208. Them following year, in 2024, the stock was trading at a high of 90.045 and a low of 80.585. The stock increased by 50.50% in the past year despite the lower P/E ratio. This could be due to the rising demand for AI technologies during 2023. AI requires a strong GPU to perform its designated task, and each GPU performance are directly affected by the performance of its DRAM which Micron produces. Hence, it is safe to predict that Micron's economic prospects could be affected by the advancements and demand for AI technology globally.

2.3. Company Breakthroughs

Over its 45 Year history, Micron has made many significant technological breakthroughs in memory industry. Micron is the pioneer for several components that we still use today and has continued to spearhead the industry for its innovation.

In 1999, Micron produced the first every DDR DRAM chipset whose performance was on par with the Direct DRAM but at a significantly lower cost. To this day, the DDR DRAM is the industry standard for high performance DRAM.

In 2011, Micron together with Intel announced the world's first 20nm MLC NAND, which is a 128Gb MLC memory that could store 1Tb of data in eight die package and physical size of a fingertip. This had set a new storage benchmark and the first of its kind to implement a planar cell structure to overcome constraints of a standard NAND.

In 2016, Micron introduced the GDDR5X with record-high, per-pin date rate enabling a massive improvement in graphics performance and GPU computation capability.
The GDDR5X has a data rate of up to 14Gb/s, double of the prior GDDR5 memory, claiming its title as the world's fastest graphics DRAM. (Micron, 2024)

2.4. Company Business Environment

2.4.1. Overview

Micron Technology is a Multi-National Corporations with operations existing in eleven different countries, three different climates and continents. With its diverse geological presence, Micron is bound to face many variables that will affect its operations locally or globally. The table summarizes some of the macro-environmental factors that could have an impact on Micron.

Socio-Cultural	Technological	Economic	Environmental	Political Legal
Changes in Consumer Preferences	Rapid Innovation and Advancements in Technology	Rapidly changing Global Economic Cycle	Investment to Sustainability Practices	International Trade Policies and Trade Wars
Ageing Population	Need for Automation	Supply Chain Disruptions	Resource Scarcity	Geopolitical Tensions
Skilled Workforce	Artificial Intelligence	Increased Cost of Production	Climate Change	

Table 1: STEEP Analysis of Micron

2.4.2. Socio-Cultural

2.4.2.1. Changes in Consumer Preferences

Consumers demand for electronic devices are some of the drivers for companies to create new and more advanced electronics. Increased demand for production of electronic devices would increase sales of Micron memory chips and parts, hence increasing the company's revenue.

Additionally, consumer demand for higher performance devices would boost the company's motivation to release newer and faster memory chip for companies.

2.4.2.2. Ageing Population

The future of our workforce is ever evolving due to changing trends and these changes are becoming more frequent. One change that we can foresee is the increase of workers over the age of fifty in the workforce. This is a result of lower childbirth rates globally. This change is both an opportunity and a risk.

According to OECD, it is expected that the OECD population aged fifty and over will reach 45% by 2050. With half of the population under fifty pursuing their studies, this leaves just 27.5% of the population under fifty in the workforce. (OECD, 2020) This creates a risk because most of the skilled workforce are reaching retirement age. With the lack of in flow of new workers into the workforce, there would be increased talent shortage, forcing employers to send their workers for upskilling. As a result, reducing the productivity of work in the workplace. As proven where there has been a significant increase of firms reporting talent shortage from 30% in 2009 to 54% in 2019. (OECD, 2020)

In Micron, with fewer mentees to learn from their mentors, essential skills needed to operate machinery and knowledge gained through experience would be lost, which would create a significantly inefficient workforce due to reduced experience and skillset.

2.4.2.3. Skilled Workforce

Students have shown to continue their compulsory education to pursue tertiary and vocational education, gaining a higher qualification necessary for an evolving society. There has been an increase of 25 – 34 year-olds attaining their degrees from 27% in 2000 to almost 50% in 2021. (OECD, 2022)

With more adults coming into the workforce with vocational training and advanced qualifications, they can assume higher skilled jobs quicker and more efficiently due to their fundamental understanding learnt during school. Companies can have a higher skilled workforce, improving the company's capabilities to expand and grow.

Students are also now required to accept student internship during their school semester to experience the working force and collaborating with colleagues in a workplace. During the internship, students will also learn firsthand skills that would be useful when they start working. Hence, the efficiency of workforce is improved over time.

2.4.3. Technological

2.4.3.1. Rapid Innovation and Advancements in Technology

Virtual Reality and Augmented Reality has been in the consumer market for quite some time, and now there has been a recent technology known as Mixed Reality where the advantage of virtual reality is combined with augmented reality. Now, users can merge the physical environment with the computer-generated imagery, allowing them to interact with this mixed environment in real time.

This technology allows Micron Engineers to interact with their machinery using computer-generated imagery to guide them in their field of work. Additionally, engineers would no longer require travelling overseas for trainings because the trainings can be taught virtually.

This also creates a large array of possibilities for Micron, as engineers could control equipment using mixed reality and remote controls, taking a step further into a remote work environment.

As a business opportunity, innovative technologies require faster processing and memory. Hence, rapid innovation and advancements in technology would become a driving force for Micron in experiencing economies of scale due to constant increasing demand for their products.

2.4.3.2. Increased Trend for Workplace Automation

The use of mechatronics has not been foreign in the manufacturing line. The use of robots and automated machinery has proven to improve the safety of workers and increased the production rate in the fabrication line.

Over reliance on mechatronics in the workplace could lead to the loss of the technical skills and capabilities of workers. When employees become too dependent on technology, they fail operate other forms of machinery without difficulty, creating a talent shortage due to a skills shortage in the workplace.

The replacement of workers to perform task in the factory will result in the potential loss of jobs of citizens. Unemployment rate will reach an all-time high, with many citizens going into debt and bankruptcy. The lack of a stable income would cause consumer spending ability to fall drastically. Without consumer spendings, companies fail to make sales. Inadvertently, creating a cycle of debt and bankruptcy collapsing the economy.

2.4.3.3. Growing implementation of Artificial Intelligence

Artificial Intelligence has been the most recent boom in the economy, with the market size expected to increase exponentially to a $USD 1.3 trillion market in 2032. (Bloomberg, 2023) This future of Artificial Intelligence is a business opportunity for a semiconductor company like Micron.

Micron being one of the top producers of memory would be affected by the increased demand for AI technology. AI technology would require large data centers to store and process substantial amounts of data quickly and accurately. Micron should take advantage of this future market by producing faster and more efficient processing units, DDR DRAM, SSD, and data center storage.

Currently, in the fabrication line, the use of AI and AI machine learning would aid workers in identifying defects and abnormalities of the product. This AI vision could be used to classify the defect to find out the reason for defect e.g., faulty machinery, and rectify the error quickly, increasing efficiency of productions and reliability of products.

2.4.4. Economic

2.4.4.1. Increasing Household Debt

Household disposable income is the spending ability of the household after taxes and household debt is the summation of all household liabilities such as loan and credit card debts. Household has reached another all-time high reaching $USD 17.3 trillion, increasing by 4.8% from Q3 2022 to Q3 2023. Additionally, credit card debt has seen the highest increase within the same period with an increase of 16.66%. This proves to be an opportunity for companies because consumers are increasing their spending on consumer goods. The increased spendings would signify the possibility of increased sales by companies, hence increasing revenue.

However, inflating debt beyond disposable income would create a cycle of debt due to interest rates. When consumers begin defaulting on payments, their spendings on consumer goods and services are bound to decrease. Hence could result companies falling into bankruptcy causing a monetary crisis. Thus, would affect all of Micron's global operations, suppliers, workforce any many more.

2.4.4.2. Supply Chain Disruption

Micron has a total of 11 manufacturing sites, spanning 6 different countries. Each site also specializes in a part of the complete process requiring other manufacturing sites to continue the fabrication and assembly process. Every facility is interdependent of one another to deliver high quality and reliable Micron products. Additionally, the raw material for fabrication comes from several suppliers and must be transported to these different sites.

With a heavy reliance on a strong supply chain network, Micron is highly vulnerable to supply chain disruptions affecting its operation. Extreme weather events could disrupt many supply routes in the region. Tropical cyclones and torrential rainfall would create unfavorable conditions for boats to dock in ports, with another possibility of the port's destruction due to weather.

The semiconductor industry is volatile with demand and supply changing abruptly due to time. When demand is high, Micron may not be able to deliver its products to its customers timely resulting in shortages and longer lead times for products. When market supply is high, Micron must compete with other companies to gain the competitive edge to push its products to customers by reducing lead time and increasing service levels.

2.4.4.3. Increased Cost of Production

The rising cost of raw materials such as oil, silicon and gold have a major impact on the production cost of manufacturing products. When the cost of materials continues to rise, profit margins of individual products will decrease. Hence limiting Micron's ability to expand operations.

As compared to larger companies in the industry such as Samsung and SK Hynix, the impact of rising cost of production would be greater on Micron. Micron would have to reduce profits or increase sale price to ensure consistent cash flow for the company. In this market, giants in the industry can keep marginal cost lower, hence able to afford to keep prices lower. In this scenario, Micron will inadvertently lose market share if it engages in a price war with Micron. Thus, Micron needs to have a wide selection of suppliers to reduce cost of materials and increase efficiency of production to reduce marginal cost.

2.4.5. Environmental

2.4.5.1. Investment into Sustainability Practices

Recently, companies have been shifting its focus to adopting green and sustainable practices in the workplace and manufacturing sites. This include obtaining clean and green energy sources, purchasing from sustainable suppliers, implementing energy saving systems.

For example, semiconductors companies would recycle water used for cooling systems and appliances through a separate filtration, de-ionizing, and reverse osmosis system. The initial investment into such systems would be high, but it could have a positive return in the future through lower production cost and lower water wastage.

Additionally, companies can purchase solar panels and wind turbines to be installed at their facilities to reduce reliance on fossil fuels for energy. Semiconductor manufacturing sites are large, hence placing solar panels on rooftops could save the company utilities cost over time. Furthermore, in the event of a power outage, essential machinery can still function before power is restored.

2.4.5.2. Resource Scarcity

The semiconductor industry is dependent on rare metals and various raw materials. For example, silicon, rare earth elements, metals like gold and copper. All these materials are limited in quantity and dependent on mining to obtains. Hence, fluctuations in the availability of these materials can severely impact the production of memory chips.

The scarcity of rare metals is a major concern in the industry, especially for rare metals such as gold. The industry would collapse if the global supply were depleted. Hence the urgency to implement recycling methods has become crucial and reducing waste would be necessary to save raw materials. Companies would also require having forward-thinking and find an alternative material of equivalent properties to gold to drive efforts of sustainability.

2.4.5.3. Climate Change

Climate change would have a major impact on Micron’s supply chain network. Climate change has caused an increase of frequency of extreme weather events due to increasing surface temperatures from global warming. These extreme weather events can cause trade routes to be disrupted due to unsafe weather conditions, floodings can damage manufacturing sites and damage products, forest fires may block roads preventing transportation of goods. These extreme weather events, if not anticipated could result in delays in shipment and loss of revenue for Micron.

Global warming would cause manufacturing sites to increase energy consumption to keep machinery cool through air-conditioning and water cooling. Hence, increasing production cost.

2.4.6. Political/Legal

2.4.6.1. International Trade Policies and Trade Wars

International trade policies are both advantages and disadvantages to companies. Some countries have agreed to signing Free-Trade Agreements with other countries to reduce trade barriers, hence promoting the trading of goods and services. Semiconductor companies are now able to reduce transportation cost and expand their market.

Tariffs, however, are taxes imposed on imported goods driving up the cost of foreign products being sold in the country. Semiconductor products would be less competitive than local products due to higher cost.

Trade wars can sometimes occur when countries impose tariffs and barriers on trade. For example, the US-China Trade War has caused high uncertainty with companies due to higher tariffs, reducing profitability and their global competitiveness. Companies must adjust to changes in international trade policies by modifying trade routes and suppliers with the aim of reducing cost.

2.4.6.2. Geopolitical Tensions

Geopolitical tensions such as wars, government instability and uprisings would be dangerous for companies such as Micron which operates globally. Geopolitical tensions decrease regional security making the areas subjectable to attacks, pirates, and terrorism. This creates an operational risk for workers and ships moving through these areas.

Government instability would incite citizens uprising and violence which would prevent normal operations from continuing, due to workers protest and raids. Production rate would fall significantly, and workers' mediocre performance would result in delays, and shortages in shipment forcing other sites to increase production to make up for lost revenue. Additionally, geopolitical tensions would reduce Micron's access to new markets due to inability to enter the market.

2.5. Competitor Analysis

2.5.1. Micron SWOT Analysis

Strength	Weakness
• **Leading industry leader in semiconductor memory and storage.** • **Diverse Product Portfolio of memory solutions e.g., DRAM, NAND, NOR.** • **Global reach and strong distributions channels.** • **Solid financial stability.**	• **Vulnerable to price fluctuations in memory market.** • **Highly dependent on small customer base.** • **High lead time and cost on new products.** • **Subjectable to supply chain disruptions.**
Opportunities	**Threats**
• **Growing demand for memory from AI, IoT and 5G technologies.** • **New emerging technologies require specific needs.** • **Demand for high-capacity SSD with faster NAND solutions.** • **Collaborations with other tech companies for joint development**	• **Strong industry competition e.g., Samsung, Intel** • **Changes in trade policies and regulations** • **New advanced memory solutions** • **Raw materials scarcity**

Table 2: SWOT Analysis of Micron

Micron has a solid stance in the semiconductor memory industry with its wide portfolio of products and technological expertise. Nevertheless, it encounters many hurdles like price fluctuations, strong competitors, and technological shifts. By leveraging on the rising demand for memory, forming strategic alliance, and persisting innovation, Micron can overcome these obstacles and capitalize on growth opportunities. Keeping a watch on market trends and changes in consumer preferences will be vital for sustaining its competitive advantage.

2.5.2. Micron’s Competitors

2.5.2.1. Samsung

Samsung is a multi-national conglomerate headquartered in South Korea with a long history of 86 years. Samsung operates in many industries including, Samsung electronics, Samsung Engineering and Samsung SDS. Now, Samsung is one of the largest semiconductor companies and a leading competitor in the memory industry, becoming a direct competitor to Micron.

Samsung is the leading manufacturer of DRAM memory by market share, accounting for 38.9% as compared to Micron accounting for 22.8%. (Statista, 2023) With a higher market share, Samsung can increase production scale reducing cost per unit and increasing profit margins of manufacturing. Additionally, Samsung has its own division of electronics, hence, can sell its memory products directly to consumers or through its electronic devices.

Samsung has pioneered new innovations for memory solutions such as HBM and V-NAND technologies improving performance and memory capacity. Despite high investments in R&D, Samsung’s diverse portfolio reduces the company’s focus on memory solutions. Unlike Micron, Samsung does not specialize in the industry instead focuses on consumer products. This slows down innovation towards memory solutions, especially with the current trend of AI requiring efficient memory to support its computing capabilities. Failing to keep up with market demands would be detrimental to Samsung, resulting in loss of revenue and market share.

2.5.2.2. Western Digital

Western Digital is a computer drive manufacturer and data storage company, which focuses on designing, manufacturing, and selling data solutions, devices, system, and cloud storage services. It is one of the largest manufacturers of the Hard Disk Drive, and more recently have move towards production of the newer solid state drive and flash memory devices, directly competing with Microns’ core products of NAND flash memory and SSD.

4Q23 Sales Ranking of Top Branded NAND Flash Makers (Unit: Million USD)

Company	Revenue		Market Share	
	4Q23	QoQ (%)	4Q23	3Q23
Samsung	4,200.0	44.8%	36.6%	31.4%
SK Group (SK hynix + Solidigm)	2,480.4	33.1%	21.6%	20.2%
WDC	1,665.0	7.0%	14.5%	16.9%
Kioxia	1,443.0	8.0%	12.6%	14.5%
Micron	1,137.5	-1.1%	9.9%	12.5%
Others	559.8	32.3%	4.9%	4.6%
Total	11,485.8	24.5%	100.0%	100.0%

NAND Market (Trend force, 2024)

In the NAND memory market, WDC places third by market share in Q4 2023 at 14.5% as compared to Micron with only 9.9%. With the growing trend of implementation of Artificial Intelligence and Cloud Computing, the need for data centers and processing centers is exponentially increasing. Both Western Digital and Micron are key players in providing the required memory for such enterprise applications. Western Digital has a slight advantage to Micron due to its diverse product portfolio from consumer to enterprise products, ensuring more stable revenue during demand fluctuations.

Additionally, there has been talks between WDC and Kioxia for a merger since 2021, despite plans not concluding, it is worth noting that a successful merger between the two companies would dynamically shift the memory landscape, with the company controlling over a third of the global supply, placing them on par with Samsung. Micron would fall out of the key players in the market, struggling to compete with their own products. Micron must ensure the merger does not happen preventing an oligopoly market where 3 firms hold over 90% of the market. Barriers of entry to the market will be higher, hence revenue from NAND memory would sink for Micron.

3. My Work as an Intern

3.1. Life as a Micron Intern

In my role as an Assembly Metrology Intern at Micron, I have been instrumental in enhancing the quality control processes for memory assembly. My key project involved developing a Real-Time Defect Analysis (RDA) program that utilizes machine-captured images to analyze underfill bleeding patterns on the die, which are critical indicators of the dispenser’s precision. This analysis is vital for identifying defects early in the manufacturing process, allowing for timely interventions that prevent the escalation of issues and reduce waste. By integrating these Python-based programs into a network dashboard, I have empowered engineers to conduct independent analyses, significantly reducing the time spent on manual inspections. This has led to a more efficient production process, with reduced downtime and increased throughput.

During my internship, I undertook two projects regarding Real-Time Defect Analysis with the Assembly Metrology department. My first project was dying level image analysis of underfill for the flip-chip. This project involves the using computer vision to detect patterns on the die, finding similarities and trends across the lot. Finding would then be displayed on a heatmap with percentages and gradients color to visualize intensity of bleeding. This dashboard would further RDA analysis for flip chip. My second project was to create a file conversion program to convert unreadable text files into usable csv files for data analysis and using this data, create a data analysis dashboard with defect mapping to expedite evaluation process.

Beyond these projects, I have created several other personal projects to improve the working efficiency of Team Members. This includes, a TIFF image frame extractor application, a Server application with webpage for future applications. Additionally, I participated in many welfare programs and sharing, expanding my network and learnings here in Micron. Towards the end of my internship, I signed up to become a panelist for a sharing with SP students, sharing about my life as an intern in Micron.

My contributions have had a direct impact on Micron's short-term operational efficiency and cost savings, while also supporting the company's long-term goals of defect reduction and yield improvement. Furthermore, by focusing on the flip chip control plan at the NAND Excellence Centre, my work supports the production of high-quality managed NAND products, which are essential for the burgeoning AI market. This not only aligns with Micron's strategic objectives but also positions the company to capitalize on the growing demand for advanced memory solutions, driving revenue growth and maintaining a competitive edge in the industry.

3.2. Underfill ADC Hotspot Detection

3.2.1. Conceiving and Design

3.2.1.1. Scope of Project

Project Attributes	Details
Project Details	Under Fill ADC Hotspot Detection
Project Supervisor	Francis Castro, Metro-RDA Manager
Project Scope	Utilize existing images and classified rejects from Underfill Defect Classification and generate hot spot location within the dies.
Project Deliverable	A Dashboard that allows for engineers to conduct independent analysis, reducing time spent on manual inspections.
Project Outcome	Hotspot identification will help engineering team to do further failure analysis and expedite the evaluation process.
Project Stakeholders	PE, Metro and SMAI Engineers and Technicians
Project Resources	Python, Virtual Machine, Streamlit
Company Objectives	Reduce man hours spent on manual inspections, Increase efficiency of failure analysis, Early detection of potential failures.
Company KPI (Short-Term)	Increased operational efficiency and Cost-savings
Company KPI (Long-Term)	Zero Defect and Zero Waste

Table 3: Underfill ADC Project Requirements

3.2.1.2. Project Approach

The project's initial objective was the development of a machine learning model designed to identify defects in die images provided by the Automatic Defect Classification (ADC) system. The model would be capable of detecting defects and visualizing them on a heat map. Afterwards, the heat map of the defects location on the die will be displayed allowing engineers to pinpoint areas with higher defect count on the die. Areas with higher defect count would indicate a recurring issue during the assembly process, enabling engineers to quickly identify and address recurring issues in the assembly process. This would facilitate rapid communication with technicians and enhance product yield.

The advent of machine learning has revolutionized the field of image classification, particularly in defect detection within manufacturing processes. In this project, I leveraged the Python programming language to develop an image classification model that processes high volumes of data, discerning subtle discrepancies in images that are not immediately apparent to engineers.

A Coder and his AI machine learning model (Generated with DALL-E 3)

The initial model encountered expected challenges, exhibiting low accuracy and high loss rates. To mitigate these issues, we employed image augmentation techniques, modifying images' colors, orientations, and zoom levels. This approach aimed to bolster the model's accuracy in classifying defects. Over the course of a week, we processed approximately 58Gb of data, encompassing 20,000 images across 50 batches, with 10 iterations each day.

To further refine the model, we introduced higher density models with additional layers, culminating in a model with 253 million parameters. Despite these enhancements, the model achieved a maximum categorical accuracy of 14%, alongside 100% precision and recall rates, indicating a tendency for overfitting.

Hence, I decided it was not possible to continue the project using machine learning and pivoted my focus towards conducting imagery defect analysis on only two defect classes, Underfill Bleeding on the Die and Underfill Bleeding on the Substrate.

Given the overfitting challenges, I shifted our focus to conduct a more targeted imagery defect analysis, specifically examining Underfill Bleeding on the Die and Underfill Bleeding on the Substrate.

For the underfill bleeding on the die, I visualized programming a code to detect the pattern of bleeding on the die. Usually, we would detect slight bleeding along the dispense side of the underfill, however due to errors, bleeding can sometimes exceed product acceptable levels. A visual pattern of such bleeding can be seen clearly by the naked eye, but there is not graphical or digital data that could be used to analyze the bleeding throughout the entire lot or batch. As shown in the image below, there is a visible increase in bleeding towards the middle and lower edge of the die. (Figure 1) Thus, the new project objective was to create a program the detect the pattern of this bleeding and produce a graphical representation of this edge for engineers to analyze further.

Figure 1. Underfill Bleeding on Controller Die (ECTC, 2019)

Using python, I created the program to detect the bleeding pattern on the die. With Canny edge detection, I cropped the ADC image to only display the die, removing the background and substrate from the image analysis. Next, the cropped image is split into a user selected number of rows and columns, adjusting the image analysis area. Since the bleeding area on the die is visually darker than the die, when converted into a grayscale image, the bleed looks black as compared to the die. Then, from each split image the bleeding area is calculated using pixel count of darker pixels with the sensitivity of calculation being user selected as well.

This process is repeated across each image in the lot, and the bleeding area is tabulated across all dies and put into an array based of row and column index. This array could be reproduced into a visual heat map with boxes with higher bleeding being a darker shade of red as shown below.

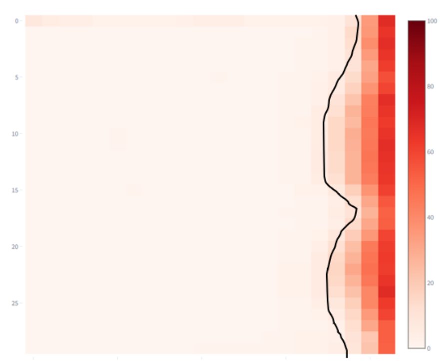


Figure 2: Underfill Heat Map of Sample Lot

From Figure 2, we can clearly see a pattern across this lot of die. There are two peaks in the dispensing of the underfill which resulted in the bleeding on the die. Form this image alone, the engineers can inform technicians to adjust the recipe to reduce defects and waste of materials. Additionally, I programmed the calculation of the average bleeding area and bleeding percentage which can be used for further analysis across more lots and over time.

For the second part of the underfill ADC image hotspot detection, I focused on analyzing the underfill bleeding on the substrate. Using a similar concept from the image cropping, I programmed a way to digitally detect the edge created by the bleeding on the substrate. Using Canny and Gaussian Blur, the code was able to detect majority of the edge, however due to each die image having different lighting conditions, the settings for edge detection are not fixed, instead must be unique for each image. This reduces the universality of the code but increases the reliability and accuracy of calculations.

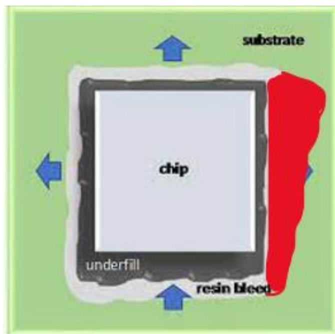


Figure 3: Underfill bleeding on substrate (ECTC, 2019)

The code will have to detect the red edge of the underfill bleeding. To get the average bleeding for the entire lot, all lot images are resized and overlayed to get an overall image of the die. This does create issues as sometimes the substrate or the wrong edges are being detected as well which reduces accuracy of calculations. Thus, to increase reliability of results, I added a segment into the code to allow the user to select the exact areas which are considered as bleeds to get the most accurate bleeding area reading.

Most of the time, I had to refer to YouTube videos to get an idea of how the code should function however, due to the different requirements of the project the code must be adjusted accordingly to the desired functions. Additionally, I would have to refer to the online documentation for the libraries which I used to modify and find out other functions which I could use for my coding project.

After some time of implementation into the workplace, I decided to integrate, Artificial Intelligence into the project. Using Density Based Spatial Clustering of Applications with Noise (DBSCAN), I implemented an unsupervised machine learning model to aid in the clustering and classification of bleeding into the backend data analysis of the dashboard. DBSCAN sets a distance within for the scatter plot, Y, and sets a min number of samples, X, for its calculations. If there are equal or more than X samples within a radius of Y from the center point, the group of samples are clustered together. This is especially efficient in processing anomalies in the scatter plot and grouping data points.

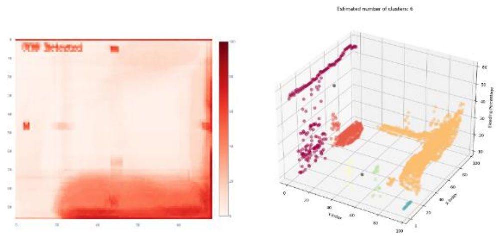


Figure 4: 3D Scatter Plot of Bleeding Hot Spots using DBSCAN.

Thus, discovering additional patterns in data, with many parameters. Hence with more data, this model could also be used to create deeper clustering and accurately decide anomalies quickly improving automation of Real-Time Defect Analysis. Additionally using Plotly , an interactive 3D Clustering Scatter Plot can be created for the engineer to view the clusters in a 720 degree view.

3.2.2. Implementing and Operating

3.2.2.1. Project Outcome

After completing my code, I started to create a digital dashboard which can be shared to anyone with the link. Ease of access and good user interface would ensure the best user experience for using my code analysis. For this project I decided to create a Streamlit Dashboard which can be created on python, has many functions and widgets, and most importantly is free to use. By using Streamlit, I would have a platform engineers can use to do their own analysis without having to understand the python code or download the code themselves.

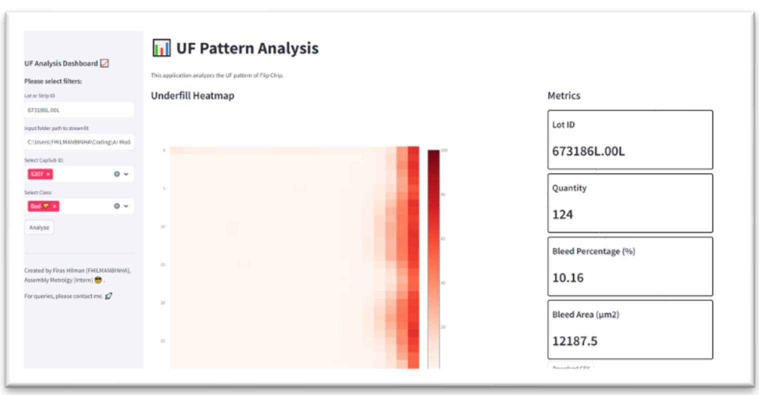


Figure 5: Streamlit Dashboard for Underfill Pattern Analysis

The dashboard creates a simple, eye-pleasing platform where all settings can be input easily and results can be displayed within the same webpage, ensuring quick and efficient analysis. Additionally, in only takes 5 clicks for the user to get the underfill heatmap and metrics, and less than 3 minutes to analyze over 4000 images. Thus, making entire batch analysis require less than 30 minutes from the image capturing to user analysis.

This is much quicker than the previous implementation which requires at least 1-1.5 hours to do a rough visual analysis based of a few sample images. The current implantation can do a thorough analysis of all dies in the lot 97% faster. Additionally, accurate data such as area and bleeding percentage can be calculated which can be further analyzed across other lots over time.

With the information provided from the dashboard, engineers and technicians can predict potential areas of failure in the underfill dispenser and adjust the recipe to reduce dispense at certain points or fix the dispenser before machine failure, reducing downtime, increasing efficiency and product yield.

The new implementation would automate laborious metrological task in the flip-chip process. Reducing man hours spent and workload of both engineers and technicians. These outcomes would inadvertently help Micron achieve its short-term and long-term goals of achieving workplace efficiency and cost saving initiatives, and zero defect and zero waste mission.

The dashboard will be evaluated based on several key performance indicators. These include the efficiency of failure analysis and the rate of early detection of potential failures, both of which are expected to improve with the implementation of the new dashboard. Cost savings, another important metric, will be measured by the reduction in man hours and increased operational efficiency. In the long term, the project aims to achieve zero defects and zero waste, with progress monitored over time. Finally, the usability and effectiveness of the dashboard will be assessed through user feedback, including surveys and interviews with the engineers and technicians who use it.

3.2.2.2. Project Impact

I was able to achieve all the project deliverables and outcomes successfully. Despite successfully analyzing images, human intervention is still required. The project has yet to reach full automation in the assembly process due to the limitations of my current skills and knowledge. Additionally, to protect Intellectual Property, some function and database linking could not be implemented. In the future, it would be great if I could come back and fully integrate an automated workflow for engineers, hence, truly achieving automation.

After inputting the lot number, the entire dashboard is fully automated. The dashboard can also send emails to relevant stakeholders automatically, removing the need for downloading the image and drafting an email manually. The dashboard is currently in operation and can be used by any engineer. Engineers are now able to use my dashboard to conduct their own analysis.

The underfill analysis for die bleeding is now automated, upscaled and specific with a reduced analysis time from 20mins to 3 mins, resulting in an 85% decrease in time taken. The underfill analysis for strip bleeding is now upscaled, and specific with a reduced analysis time from 20mins to 5mins, a 75% decrease.

However, due to limited processing power and memory, the dashboard has an average runtime of about 2-3 mins. Future improvements to further automate the dashboard can be made, as well as implementing AI to analyze the data and AI Chatbots could be added to further improve the dashboard.

As a final implementation, I created an emailing service into the dashboard. After analyzing, engineers can opt to send out a customized analysis report to other engineers to share findings and data. Using HTML, CSS and SMTP, an email can be delivered through code using the Micron server without requiring the use of third-party email applications such as Outlook and Gmail. Additionally, a custom template and structure can be crafted using HTML to suite the needs of engineers.

3.3. Wire Bond and Die Attach Automated Strip Hotspot and Reject Viewer

3.3.1. Conceiving and Design

3.3.1.1. Scope of Project

Project Attributes	Details
Project Details	Wire Bond and Die Attach Automated Strip Hotspot and Reject Viewer
Project Supervisor	Francis Castro, Metro-RDA Manager
Project Scope	Convert existing text files to a form of database for defect analysis. Create a shared platform for engineers to conduct RDA for ATI Inspection
Project Deliverable	A defect dashboard for RDA, Defect Strip Map with Image, Automated file conversion, data extraction and uploading
Project Outcome	Hotspot identification will help engineering team to do further failure analysis and expedite the evaluation process.
Project Stakeholders	Metrology Engineers and Technicians, Process Equipment Engineers
Project Resources	Virtual Machine, Python, Tableau, Flask API
Company Objectives	Expedite evaluation process for failure analysis
Company KPI (Short-Term)	Increased operational efficiency and Cost-savings
Company KPI (Long-Term)	Zero Defect and Zero Waste

3.3.1.2. Project Approach

The metrology department utilizes a machinery by Advanced Technology Inc, a Korean company specializing in metrology and inspection. This machine is used in many industries, semiconductor, LED, PCB and even Photo-Voltaic Solar Industry. The ATI inspection machine can be used for wafer-inspection, mask inspection and many others. The system is also designed to provide high throughput, high-resolution, and real-time auto focusing. Most importantly, the machine offers IR inspection for defect, crack and chippings which are essential inspection requirements for Micron who produces memory products. (ATI, 2015)

This high precision machine can be programmed with different recipes and trained with defect types for different uses allowing for a broad usage of inspection methods along the assembly line. Additionally, it can be used to automatically classify defects, but still requires technicians to filter out overkills and classify incorrect defects. These results will be uploaded to a network folder with lot information and indexing of defects. Information uploaded includes, lot id, recipe id, device id, date, time, and defect code.

The problem with the uploaded information is, the data is written into a .txt file which creates issues when processing this data because it is not in a set format or table. Hence, a python code for processing and reading the .txt file and re-writing the data into an appropriate file format is required. Additionally, due to the complexity of processing such information from a .txt file, there is currently no data visualization for this RDA process in the assembly line. Engineers had to manually pull the .txt file, filtering for the exact lot or strip which requires additional analysis to quickly figure out the root cause of an issue. The time taken to find for these data would cost the company due to increased downtime and defect count.

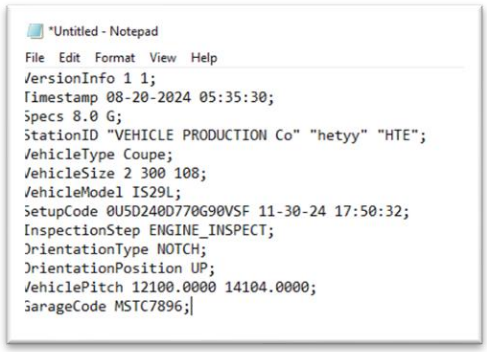

*Untitled - Notepad
File Edit Format View Help
VersionInfo 1 1;
Timestamp 08-20-2024 05:35:30;
Specs 8.0 G;
StationID "VEHICLE PRODUCTION Co" "hetyy" "HTE";
VehicleType Coupe;
VehicleSize 2 300 108;
VehicleModel IS29L;
SetupCode 0U5D240D770G90VSF 11-30-24 17:50:32;
InspectionStep ENGINE_INSPECT;
OrientationType NOTCH;
OrientationPosition UP;
VehiclePitch 12100.0000 14104.0000;
GarageCode MSTC7896;

Figure 6: Sample .txt file of uploaded information from ATI machine

The sample above is a replication of the .txt file uploaded from the machine. As we can see, the data is separated by lines, semi-colons, commas and "". Hence it would be difficult to automatically separated these values and format them into a suitable table. Additionally, there is also a 17 column table with multiple rows below which must be formatted into a table. Using python, the program would separate all the lines in the file into an array. Next, by reiterating over each line the program would match a certain string or value for strings. For example, I programmed the code to search for "VehicleType", When the code returns True, the string within each line is further separated into another array using the split() function, which separate the line to ["VehicleType", "Coupe;"]. Since we want to filter the data, I used the array [1] to return the second element in the array "Coupe;". Afterwards, using the strip() function, I removed the ";" from the string to get the final data of "Coupe". This is a simplified version of the actual process; the actual process requires more data cleaning and formatting before it is usable.

```python
vehicle_type = [line for line in lines if line.startswith('VehicleType')][0].split()[1].rstrip(';')
```

Figure 7: Sample code for simplified data cleaning of .txt file

Using the same concept of filtering through lines using the function line. startwith('String'), where lines in the text file is enumerated and returns a list with each line being an item in the list, key words can be picked out to indicate the starting point and ending point of a table. Next, I had to program a way to filter out each row and column of the table and place them into a fixed data frame. Using the split function, each string is separated and placed into an array.

An essential part of data processing and analysis is data cleaning. The data provided by the ATI machine is in numbers and have repeated data across indexes. For context, the ATI machine analyses a strip board of die, and sometimes they can be multiple data lines for a single line, hence removing of irrelevant data is required to get the most accurate analysis. Thus, using a list of numbers representing defect type, the python code would specify which row item to conduct a binary comparison with. If the value returned from the row item matches any of the values in the list of defect type, the python script would replace the number with the corresponding defect type such as “Contamination”, or “Broken Die”. This would make it easier for engineers to know the defect type without having to look up the corresponding defect type.

```
# Split the line into columns based on a space
columns = line.strip().split()
columns = [value.rstrip(';') for value in columns]
[redacted]

row = [[redacted]] + columns[1:10]

delete_values = ['10','99']
if row[15] in delete_values:
    row = [[redacted]] + columns[1:10] + [1]
else:
    row = [[redacted]] + columns[1:10] + [0]

if row[15] in value_mapping:
    # Replace the value
    row[15] = value_mapping[row[15]]
```
Figure 8: Sample code for data extraction

After extraction of the data, the data is configured to a list (rows) of another list (row). To make the data easier to read, the list of (row) is sorted based of their respective location index on the strip board, starting from 0,0 to 20,4. Once the list(rows) are sorted and cleaned, the list can be converted into a pandas data frame using the concat() function, to be finally saved into a csv file for data analysis.

As new files are consistently updated by technicians in the assembly line, it becomes difficult to manually run the python script for every single .txt file that gets uploaded. As of drafting this report, there is an estimated 2000 .txt files at any one point of time and with new uploaded files coming at inconsistent timing and amounts. To tackle this problem, I implemented a file system event handler to create events when it detects file creation, modification, or removal from the folder. Hence, whenever there is an uploaded file being added into the tracked folder, the watchdog handler would raise an event to run the function of converting the .txt file to a .csv file for data analysis.

```
class MyHandler(FileSystemEventHandler):
    def on_created(self, event):
        filename = event.src_path
        if filename.endswith('.001'):  # check if the new file is a.001 file
            # Call your csv converter function
            process_file(filename)
            logging.info(f"Detected new file: {filename}")
            print(f'File {filename} has been added and converted.')
```

Figure 9: Sample code of event handler

This event handler would continuously run in the background if the code were running, and the terminal is not closed. This task is impossible, especially for an intern with a single laptop with limited access. Thus, after discussing with my manager and consulting with the department director and IT Team, I was able to get an approval for a virtual machine whose main purpose is to do nothing but run code 24/7, 365 days a year without a break. This removes all human involvement in the file processing process, automating the data extraction. Furthermore, this ensures usability and easy maintenance of the code and software after the end of my internship. The virtual machine allows multiple users to access this software. Users can also add their own applications for use on the same operating system to create a centralized machine for use.

However, only the first problem has been resolved because the data is still in a .csv file and not in any proper data visualization platforms for shared viewing across the department. There were two platform I considered using for creating a data visualization dashboard, PowerBI which I was more familiar with, and Tableau. After using both platforms for everyday tasks, I realized that Tableau was more interactive and offered better capabilities such as extraction from data source, unionization of data files, advanced filtering, web servers for sharing with team members and alert. Hence, Tableau was the better solution for data visualization.

3.3.2. Implementing and Operating

3.3.2.1. Project Outcome

To begin using tableau, I had to configure the data source to be accessible on the network tableau server. This required the aid of many other engineers to troubleshoots and implement the connection between the data source and the Micron server. I opened a request to counterparts in India and Malaysia to aid with the administrative and technical onboarding of the data source to the server. This ensured the data was accessible for use by the server for conducting calculations and visualizations. Without a successful connection of the file directory, the user must manually update the data. Since my data source is consistently updated, it is vital for automated update and refreshing of the data to provide correct information to the engineers.

After the data source was properly configured with the proper extract refreshes, the dashboard can now be created with quick query durations despite large data sets.

Using Tableau, I created multiple data graphs to represent useful information to engineers, such as total defect count for the respective day, week, and month in the form of a stacked bar chart. This allows the graph the represent the running total based of the type of defect differentiated by color. Additionally, to aid the analysis of these graphs, I included multiple adjustable filters such as range of dates, defect type and strip type. By changing these filters, engineers can view the chosen defect and strip type across a period, to find a correlation between the variables or anomalies. This added analysis prompts engineers to rectify ongoing issues resulting in the defects, reducing probability of future defects and increased production cost. By reducing defect, Micron can increase production yield, reducing backlog and increasing profits.

Figure 10: Sample Tableau Dashboard

This dashboard improves lot level Real-time defect analysis, by comparing multiple variables such as defect, strip, and assembly process. Accurate analysis requires both the macro and micro inspection of the assembly process. Hence, another dashboard is needed to analyze wafer level information.

Using the x-index and y-index provided by ATI machine, a grid map can be created to map out the location of defects on the strip. The grid map would visualize the proportion of defects and non-defects and the defect type for a particular lot. This allows for engineers to pick out patterns in the type of defect, such as a higher percentage cracked die along the x row providing engineers with crucial information for the inspected process. Hence, the engineers can deduce an issue with the assembly process particularly along the x row of the strips and rectify the problem as quickly as possible.

Additionally, with implementation of an API, engineers can view selected defects to conduct added analysis without requiring to fish for the image in a directory of 3000-4000 images. By simply hovering over the data point, the exact defect image would be displayed on the same dashboard, enabling quick viewing, and scanning of defects for the strip. In the past, engineers had to manually view the image from the inspection machine itself, and use an iPad to share the defect or browse through several files to get the image.

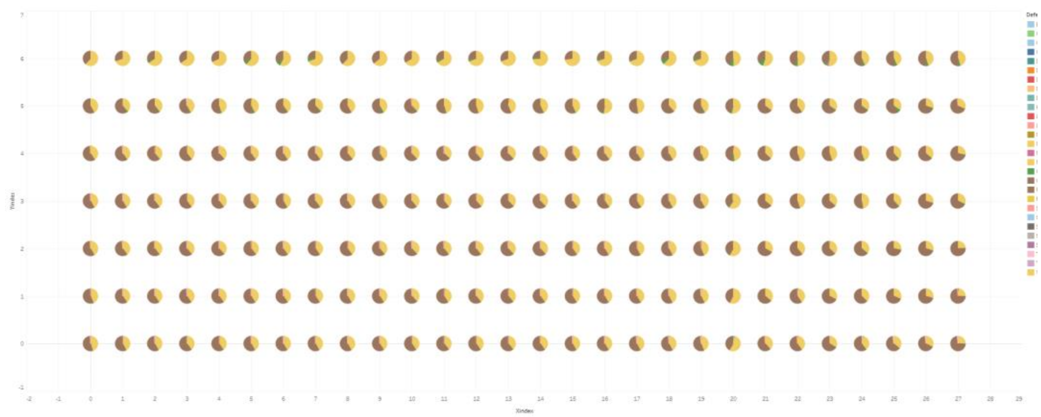


Figure 12: Sample defect grid map with pie charts.

To further automate the analysis process, the report is emailed to team members every week, providing prompt updates of the assembly yield. Alerts can be set, whenever there is a sudden increase or anomaly in the data. This completes the entire data analytics process, providing a fully automated system for extraction, reading, displaying and distribution of data, removing human from the equation to focus on other key factors in the assembly line.

3.3.2.2. Project Impact

I was able to successfully achieve all project deliverables and exceeded the requirements for this project. The project is currently in use by engineers to provide prompt updates on defect count by ATI machine inspections. With the automated file conversion python script, both images and related data are exported and available for use for further analysis.

The entire process is automated, as compared to previously where engineers must copy and paste the data manually and was limited to strip level analysis which takes about 10mins. Now the file conversion streamlines the process to immediate conversion with more data and images. Additionally, image viewing now produces immediate results as compared to previously where the image had to be filtered through over 400 different photos.

This file conversion and dashboard has been implemented to Micron's operation to cover all inspections done by ATI machine. It has produced desired results by saving Micron, over 15 mins per strip for file conversion, updated data visualization, immediate image viewing through a new and full automated process.

With the use of a virtual machine, the python script runs in the background on the server, ensuring that no files are missed and reduces unnecessary computer processing power. This provides immediate conversion when a strip has completed inspection, providing up-to-date data. Then, with data extraction from Tableau, data is consistently refreshed and saved on the server. This decreases the query time of data by 5mins, providing quick data visualization and reduces chances of server crashes from live connections.

3.4. Web Server Application with Flask API

3.4.1. Problem and Ideation

During my internship, I noticed that my department engineers do not have a central website for all the links and folders needed for their work. Instead, they relied on saving these links on a text file or by memory. Especially for new hires, these platforms and links would be difficult to memorize quickly. Additionally, my internship projects are mostly web application and server dashboards with unique URLs and source codes, learning materials, and documentation are stored on a network folder. This was designed using HTML and CSS with JavaScript for frontend processing.

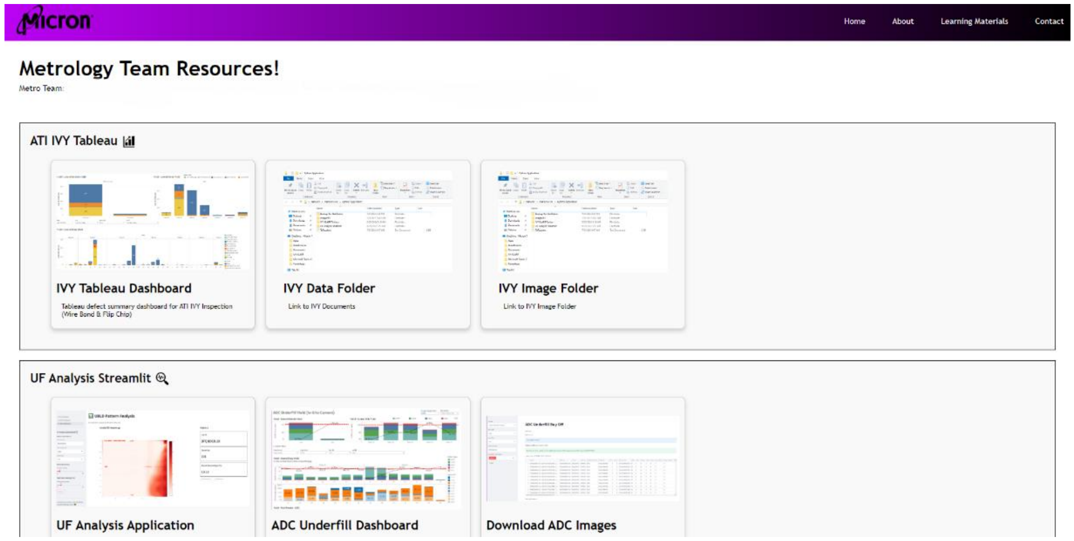


Figure 13: Web Server Application

Hence, to ease the process of navigating through links, websites, and folder, I created a multipage website with Flask API for rerouting, rendering images, request handling and database integration. This webpage would serve as an all-inclusive web hub specifically for the metrology department holding all the relevant links for the department. This would cut down the number of links from more than 10 to just 1 main link.

3.4.2. Implementation and Security

After debugging and testing the API over several uses, the API was onboarded onto a virtual machine to ensure the server is always running. This is essential because these applications should be always accessible and are running watchdog and scheduled events to provide immediate return of data. Thus, data is kept up to date for the most accurate real-time defect analysis.

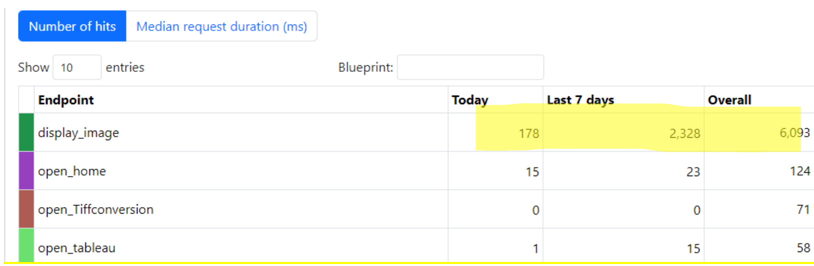
Micron being a multinational company with over 55,000 patents, holds a substantial amount of confidential information , if leaked could cost the company millions of dollars. Hence to reduce the risk of corporate spies stealing this information, I implemented encrypted and secure communications between all web applications and servers using the HTTPS. Reducing the risk of information leakage and hacking due to a weak point in the servers.

3.4.3. Outcome

Navigation of websites and server are reduced by 66.66% from 30 secs to 10 secs, and clicks are reduced from 3-5 to 1 click. Additionally, risk of losing the links to websites and data folder are significantly reduced by having a single website storing all these different links. Engineers would also find it easier to use my dashboards and python programs because relevant folders and links are together. Troubleshooting for server side issues are also simpler by having another dashboard and database for the runtime of each process and logging of every transaction, allowing for efficient debugging and improvements.

3.5. Company Impacts

The projects were fully implemented and in operation since 17 July 2024. During the next few weeks, I tracked the usage of the programs and applications. During this time, the Tableau dashboard has been used over 600 times, inspecting over 6000 units. On average, a total of 200 units are inspected each day, amounting to about 50 Man Hours saved daily. After some calculations, a total of 2248 hours have been saved since the start date of the programs in operations, over 700 Man hours saved for converting almost 3000 files and 1000 images. These programs have significant impacts, providing valuable information to team members. As of now, there are ~30 Unique users, both technicians and engineers and the data has impacted more than 100 team members in process engineering.



Endpoint	Today	Last 7 days	Overall
display_image	178	2,328	6,093
open_home	15	23	124
open_Tiffconversion	0	0	71
open_tableau	1	15	58

Figure 14: API usage tracking

This project is currently in the initial stages and has potential to expand to other assembly process, increasing its impacts of work efficiency by multiple fold. Machine learning, data regression and clustering are in the talks of being implemented using this data to create improved RDA process and automated classification and pattern detection, expediting the RDA process, reducing holding time and achieving zero defect, zero waste.

4. Reflection and Learning Points

4.1. Reflection on CDIO skills & SDL during internship experience

During my first few weeks of internship, I spent most of my time studying the assembly process in Micron and the sampling and testing methods conducted by Metrology to ensure quality and reduce defects. Particularly, I focused my efforts on the flip-chip assembly process and the underfill dispense. The underfill is a tricky process which is subjectable to multiple types of failure such as bleeding, contamination, and lack of dispense. Micron has strict thresholds for these defects because even slight defects could result in poorer performance from our products, reducing the quality.

Before I came to Micron, Micron has implemented an Automatic Defect Classification (ADC) by using computer vision to classify defects and non-defects. The ADC has high accuracy and precision, however sometimes there maybe cases of overkilling or underkilling. Hence, one of my tasks was to filter through the sample images to filter overkilling and underkilling, report to my supervisor with the aim of further improving the ADC. While filtering through the images, I notice dispense patterns among the defects and non-defects. These patterns only occur in certain strips and dispense machine which are classified as anomalies. However, conducting this process manually was highly time consuming, especially when dealing with a high volume of images amounting to over 4000. I realized a problem in the Real-time Defect Analysis (RDA), there was limited analysis on a die level, the process is inefficient due to high volume, it is inaccurate because it relies on human sight instead of data, and the process was human dependent, requiring a trained engineer to inspect the lot manually and visually.

Using my knowledge and experience from SP, I conceived a plan to create a program to automate RDA for underfill inspections with the aim of reducing man hours and increasing efficiency. For this program, I decided to code using python , a language I have never coded before. To increase my proficiency, I began learning computer vision, machine learning and data processing with python by watching YouTube videos whenever possible. I chose python for its versatility and ability to perform the necessary task for this project. During the designing phase of my project, my self-directed learning was pivotal. I had to explore various image analysis methods and algorithms that would tailor to my project requirements. Additionally, with machine learning, I had a lot of trial and error to achieve a suitable model to classify the images to ensure a high accuracy and precision of the RDA program so it can accurately detect underfill bleeding patterns.

Learning to pivot and change my approach to the problem was what made my project successful. After experimenting using computer vision and supervised machine learning, I realized the current approach did not yield the desired results hence, I pivoted to used mathematical calculations to detect bleeding patterns and plot diagrams based of the results.

After successful testing an execution, I sought feedback from my department to provide insights and concerns with the program. As the main stakeholders, I needed to tailor the program to their needs and requirements. At the same time, I began implementing the program onto a virtual machine for network deployment. The network deployment created a few problems due to issues of permission and access, limited processing power and security. Hence, I utilized online resources and documentations from GitHub to troubleshoot issues and optimize code to reduce memory usage by the calculations. Thus, refining the program’s functionality and usability.

For my second project, I had to create a data analysis dashboard for ATI machine. The main issue was the data being stored a txt file with a mix of words and numbers with no fixed format throughout the txt file. Hence, I created an automated python program to convert the data to a readable csv for data analysis. I used tableau as a data visualization program however this created multiple issue. Micron has a dedicated tableau server for IP reasons hence data needs to be connected to the server through SharePoint, OneDrive, or network folders. Due to lack of available resources, I needed to onboard the network folder where the CSVs are stored to the server using the DNS. I faced many technical issues for connecting the data source. Thus, I reached out to other engineers who are familiar with the issue to find solutions for the problem. I was able to connect and engage with many new engineers from different departments. I was able to learn so much from them, and by combining their shared knowledge and experience, I am now able to automatically connect my data to the server with high query speeds and low lag.

Self-directed learning has certainly helped me throughout my internship, however the learning and knowledge passed down by other engineers has been vital for making my project a success, they provided an alternative viewpoint and helped me pivot my approach to the problem. By implementing, the skills thought by SP such as CDIO and Plan-Do-Check-Act by Micron, I was able to successfully complete my internship with Assembly Metrology RDA at MSB, Micron.

4.2. Learning Points and Recommendations (to the Company)

Throughout my internship, I actively sought feedback on my Real-Time Defect Analysis (RDA) program, managing my learning by incorporating suggestions from senior engineers and quality control experts. This iterative process not only improved the program but also deepened my understanding of metrology and software development. I regularly reviewed the RDA program's performance metrics, evaluating its effectiveness in detecting defects. By analyzing data trends, I was able to refine the program's algorithms, leading to more accurate and reliable defect identification. One of my key recommendations was to integrate machine learning techniques to further enhance the RDA program's accuracy. By training a model on historical defect data, the program could predict potential issues before they occur, shifting from reactive to proactive quality control. I suggested that Micron could streamline its quality control workflow by automating the data collection process. This would reduce human error and ensure a consistent data set for analysis. The benefits of implementing these recommendations include increased efficiency, reduced waste, and improved product quality. The trade-off might be the initial investment in machine learning infrastructure and the need for ongoing training for staff to adapt to the innovative technology.

4.3. Lessons Learnt

I should have engaged in relevant coursework and practical labs to gain foundational knowledge in metrology and software development. Participating in industry webinars and workshop or even studying more about the semiconductor industry would allow me to understand current trends and challenges beforehand. Additionally, I should have learnt about the business and products of Micron prior to working. If I knew the project I was involved in, I would have practiced coding regularly, familiarizing myself with different approaches and coding techniques. I would also have started learning python with the aim of sharpening my programming skills for developing a Real-Time Defect Analysis Program for Micron.

I learned that I thrive in environments that challenge me to innovate and problem-solve. My ability to adapt and learn new technologies quickly was a key factor in my success. I discovered the importance of precision and proactive quality control in the semiconductor industry. Collaborating with a diverse team taught me the value of different perspectives in achieving a common goal. The experience highlighted the industry's fast-paced nature and the constant need for technological advancements to stay competitive.

Juniors should be in touch with the latest trends in the industry and constantly upskill their technical proficiency in their field of work. Juniors need to understand the industries' challenges and opportunities to become a strong asset to any company that they join.

To become more work ready, our juniors need to be comfortable with change and adapt to the unfamiliar environment of a workplace. Students need to be nurtured to not follow a guideline instead should be thought to innovate and be creative with their solutions to a problem.

4.4. Conclusion

During my internship at Micron, I significantly enhanced the quality control process for memory assembly by developing a Real-Time Defect Analysis program. This python-based tool analyzes underfill bleeding patterns on dies, pinpointing defects early to prevent issues and reduce waste. By integrating these systems into a network dashboard, I enabled our engineers to conduct efficient, independent analysis, reducing manual inspection time and increasing production throughput. Mu work directly contributed to Micron's operational efficiency and cost savings, while also supporting the production of high quality managed NAND products for the booming AI market. These efforts align with Micron's strategic goals and bolster its position in the competitive memory solutions industry.

Annex A

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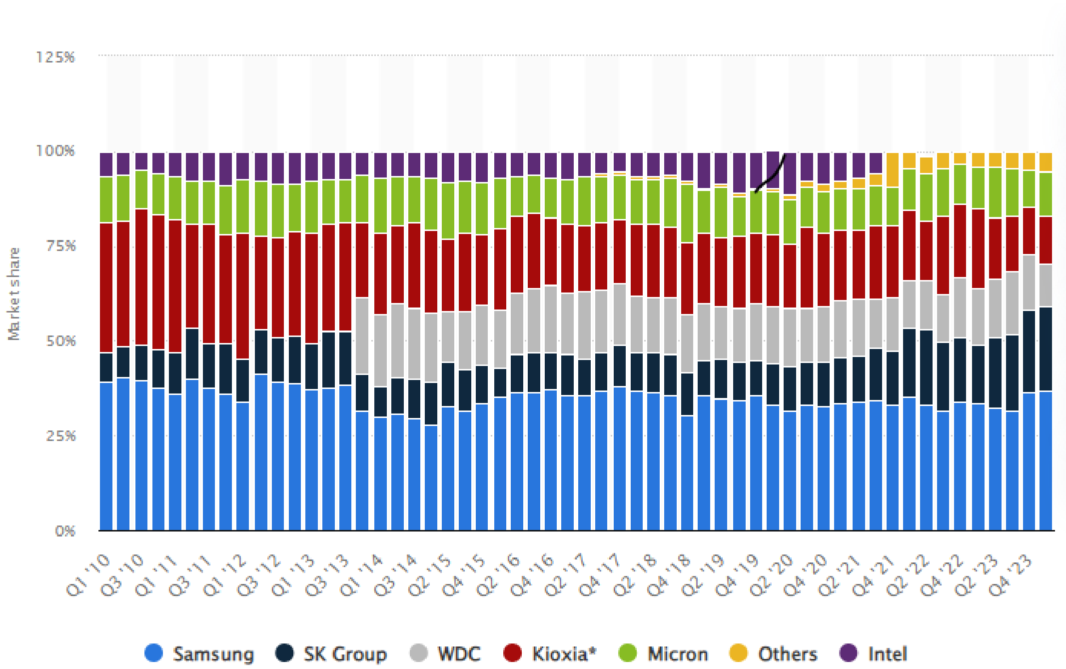
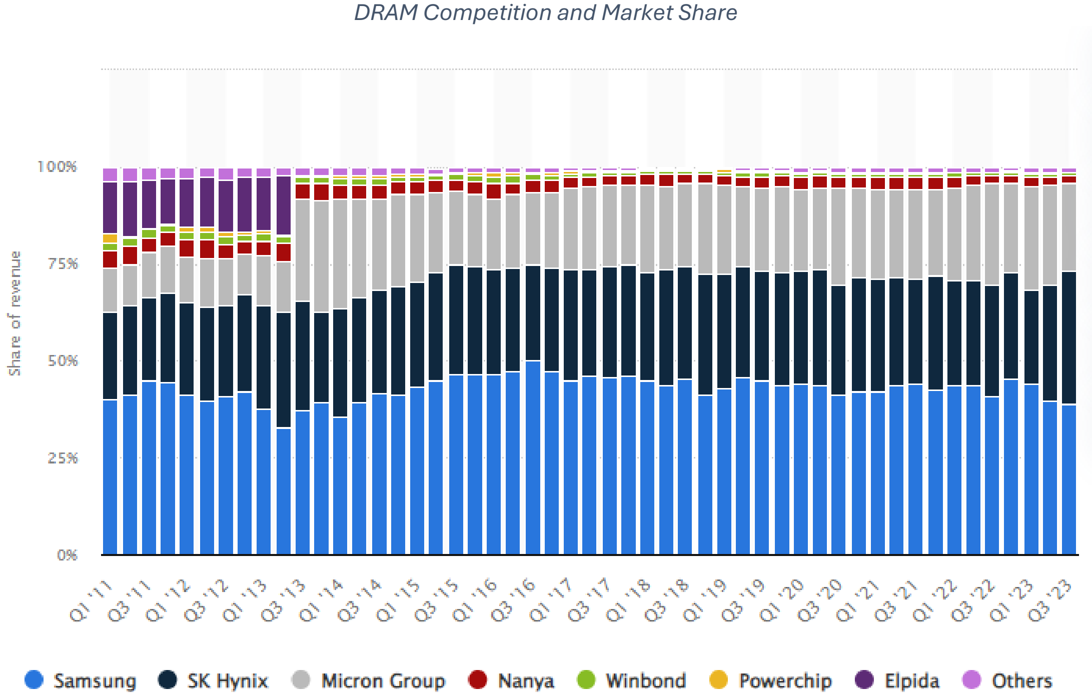
Annex B

NAND Competition and Market Share

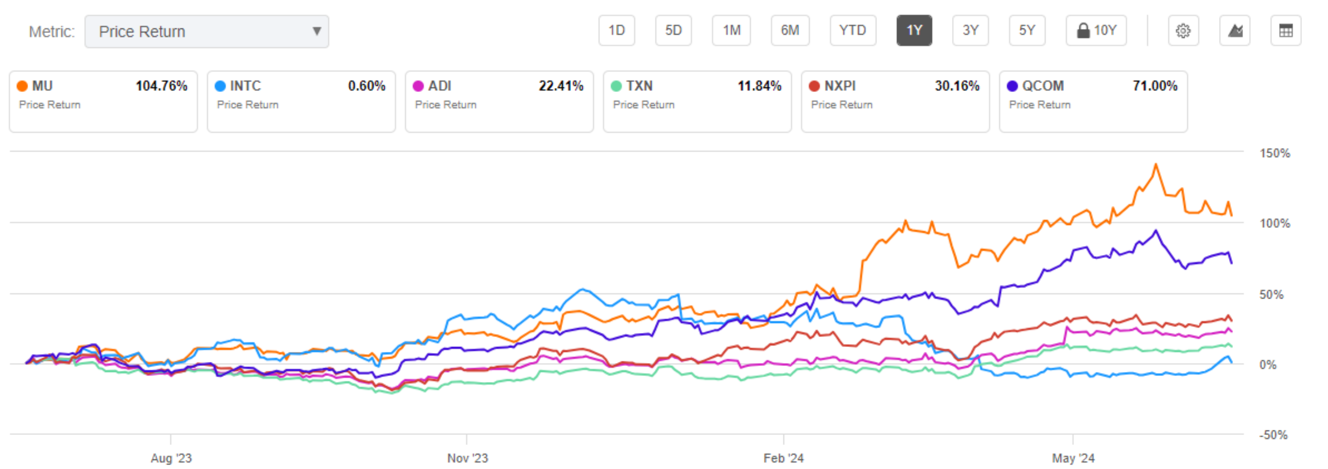


DRAM Competition and Market Share



Micron Competitor Stock Comparison

	MU	INTC	ADI	TXN	NXPI	QCOM
Company Name	Micron Technology, Inc.	Intel Corporation	Analog Devices, Inc.	Texas Instruments Incorporated	NXP Semiconductors N.V.	QUALCOMM Incorporated
Sector	Information Technology	Information Technology	Information Technology	Information Technology	Information Technology	Information Technology
Industry	Semiconductors	Semiconductors	Semiconductors	Semiconductors	Semiconductors	Semiconductors
Market Cap	151.23B	148.44B	118.26B	185.39B	72.20B	233.02B
Enterprise Value	156.02B	182.89B	124.02B	189.19B	79.39B	234.63B
Employees	43,000	124,800	26,000	34,000	34,200	50,000
SA Analysts Covering	23	14	2	8	3	11
Wall St. Analysts	37	46	31	33	30	36



Micron Supervisory Management Chain

Supervisory Management Chain 8 items

Organization	Manager	Phone Number
Chief Executive Officer ([redacted]	[redacted]	[redacted]
CEO Staff ([redacted])	[redacted]	[redacted]
Global Operations ([redacted]	[redacted]	[redacted]
VP of Operations ([redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
MSB ([redacted]	[redacted]	[redacted]
MSB PEE ([redacted]	[redacted]	[redacted]
MSB PEE ([redacted]	[redacted]	[redacted]

Annex C

Micron Technology, Inc. Reports Results for the Second Quarter of Fiscal 2024

March 20, 2024 at 4:07 PM EDT

AI demand and tight supply accelerate return to profitability

BOISE, Idaho, March 20, 2024 (GLOBE NEWSWIRE) -- Micron Technology, Inc. (Nasdaq: MU) today announced results for its second quarter of fiscal 2024, which ended February 29, 2024.

Fiscal Q2 2024 highlights

- Revenue of $5.82 billion versus $4.73 billion for the prior quarter and $3.69 billion for the same period last year
- GAAP net income of $793 million, or $0.71 per diluted share
- Non-GAAP net income of $476 million, or $0.42 per diluted share
- Operating cash flow of $1.22 billion versus $1.40 billion for the prior quarter and $343 million for the same period last year

"Micron delivered fiscal Q2 results with revenue, gross margin and EPS well above the high-end of our guidance range — a testament to our team's excellent execution on pricing, products and operations," said Sanjay Mehrotra, President and CEO of Micron Technology. "Our preeminent product portfolio positions us well to deliver a strong fiscal second half of 2024. We believe Micron is one of the biggest beneficiaries in the semiconductor industry of the multi-year opportunity enabled by AI."

Quarterly Financial Results

	GAAP(1)			Non-GAAP(2)		
(in millions, except per share amounts)	**FQ2-24**	**FQ1-24**	**FQ2-23**	**FQ2-24**	**FQ1-24**	**FQ2-23**
Revenue	$ 5,824	$ 4,726	$ 3,693	$ 5,824	$ 4,726	$ 3,693
Gross margin	1,079	(35)	(1,206)	1,163	37	(1,161)
percent of revenue	*18.5%*	*(0.7%)*	*(32.7%)*	*20.0%*	*0.8%*	*(31.4%)*
Operating expenses	888	1,093	1,097	959	992	916
Operating income (loss)	191	(1,128)	(2,303)	204	(955)	(2,077)
percent of revenue	*3.3%*	*(23.9%)*	*(62.4%)*	*3.5%*	*(20.2%)*	*(56.2%)*
Net income (loss)	793	(1,234)	(2,312)	476	(1,048)	(2,081)
Diluted earnings (loss) per share	0.71	(1.12)	(2.12)	0.42	(0.95)	(1.91)

Investments in capital expenditures, net(2) were $1.25 billion for the second quarter of 2024, which resulted in adjusted free cash flows(2) of negative $29 million. Micron ended the second quarter of 2024 with cash, marketable investments, and restricted cash of $9.72 billion. On March 20, 2024, Micron's Board of Directors declared a quarterly dividend of $0.115 per share, payable in cash on April 16, 2024, to shareholders of record as of the close of business on April 1, 2024.

Business Outlook

The following table presents Micron's guidance for the third quarter of 2024:

FQ3-24	**GAAP(1) Outlook**	**Non-GAAP(2) Outlook**
Revenue	$6.60 billion ± $200 million	$6.60 billion ± $200 million
Gross margin	25.5% ± 1.5%	26.5% ± 1.5%
Operating expenses	$1.11 billion ± $15 million	$990 million ± $15 million
Diluted earnings per share	$0.17 ± $0.07	$0.45 ± $0.07

Further information regarding Micron's business outlook is included in the prepared remarks and slides, which have been posted at investors.micron.com.

Investor Webcast

Micron will host a conference call on Wednesday, March 20, 2024 at 2:30 p.m. Mountain Time to discuss its second quarter financial results and provide forward-looking guidance for its third quarter. A live webcast of the call will be available online at investors.micron.com. A webcast replay will be available for one year after the call. For Investor Relations and other company updates, follow us on X @MicronTech.

About Micron Technology, Inc.

We are an industry leader in innovative memory and storage solutions transforming how the world uses information to enrich life *for all*. With a relentless focus on our customers, technology leadership, and manufacturing and operational excellence, Micron delivers a rich portfolio of high-performance DRAM, NAND, and NOR memory and storage products through our Micron® and Crucial® brands. Every day, the innovations that our people create fuel the data economy, enabling advances in artificial intelligence and 5G applications that unleash opportunities — from the data center to the intelligent edge and across the client and mobile user experience. To learn more about Micron Technology, Inc. (Nasdaq: MU), visit micron.com.

Forward-Looking Statements

This press release contains forward-looking statements regarding our industry, our strategic position, technology trends and developments, market demand, and our financial and operating results, including our guidance for the third quarter of 2024. These forward-looking statements are subject to a number of risks and uncertainties that could cause actual results to differ materially. Please refer to the documents we file with the Securities and Exchange Commission, including our most recent Form 10-K and Form 10-Q. These documents contain and identify important factors that could cause our actual results to differ materially from those contained in these forward-looking statements. These certain factors can be found at investors.micron.com/risk-factor. Although we believe that the expectations reflected in the forward-looking statements are reasonable, we cannot guarantee future results, levels of activity, performance, or achievements. We are under no duty to update any of the forward-looking statements to conform these statements to actual results.

(1) GAAP represents U.S. Generally Accepted Accounting Principles.
(2) Non-GAAP represents GAAP excluding the impact of certain activities, which management excludes in analyzing our operating results and understanding trends in our earnings, adjusted free cash flow, and business outlook. Further information regarding Micron's use of non-GAAP measures and reconciliations between GAAP and non-GAAP measures are included within this press release.

MICRON TECHNOLOGY, INC.
CONSOLIDATED STATEMENTS OF OPERATIONS
(In millions, except per share amounts)
(Unaudited)

	2nd Qtr. February 29, 2024	1st Qtr. November 30, 2023	2nd Qtr. March 2, 2023	Six months ended February 29, 2024	Six months ended March 2, 2023
Revenue	$ 5,824	$ 4,726	$ 3,693	$ 10,550	$ 7,778
Cost of goods sold	4,745	4,761	4,899	9,506	8,091
Gross margin	1,079	(35)	(1,206)	1,044	(313)
Research and development	832	845	788	1,677	1,637
Selling, general, and administrative	280	263	231	543	482
Restructure and asset impairments	—	—	86	—	99
Other operating (income) expense, net	(224)	(15)	(8)	(239)	(19)
Operating income (loss)	191	(1,128)	(2,303)	(937)	(2,512)
Interest income	130	132	119	262	207
Interest expense	(144)	(132)	(89)	(276)	(140)
Other non-operating income (expense), net	(7)	(27)	2	(34)	(2)
	170	(1,155)	(2,271)	(985)	(2,447)
Income tax (provision) benefit	622	(73)	(54)	549	(62)
Equity in net income (loss) of equity method investees	1	(6)	13	(5)	2
Net income (loss)	$ 793	$ (1,234)	$ (2,312)	$ (441)	$ (2,507)
Earnings (loss) per share					
Basic	$ 0.72	$ (1.12)	$ (2.12)	$ (0.40)	$ (2.30)
Diluted	0.71	(1.12)	(2.12)	(0.40)	(2.30)
Number of shares used in per share calculations					
Basic	1,104	1,100	1,091	1,102	1,091
Diluted	1,114	1,100	1,091	1,102	1,091

MICRON TECHNOLOGY, INC.
CONSOLIDATED BALANCE SHEETS
(In millions)
(Unaudited)

As of	February 29, 2024	November 30, 2023	August 31, 2023
Assets			
Cash and equivalents	$ 8,016	$ 8,075	$ 8,577
Short-term investments	990	973	1,017
Receivables	4,296	2,943	2,443
Inventories	8,443	8,276	8,387
Other current assets	1,690	791	820
Total current assets	23,435	21,058	21,244
Long-term marketable investments	627	720	844
Property, plant, and equipment	37,587	37,677	37,928
Operating lease right-of-use assets	642	648	666
Intangible assets	414	416	404
Deferred tax assets	664	781	756
Goodwill	1,150	1,150	1,150
Other noncurrent assets	1,199	1,326	1,262
Total assets	$ 65,718	$ 63,776	$ 64,254
Liabilities and equity			
Accounts payable and accrued expenses	$ 4,680	$ 3,946	$ 3,958
Current debt	344	908	278
Other current liabilities	1,235	1,108	529
Total current liabilities	6,259	5,962	4,765
Long-term debt	13,378	12,597	13,052
Noncurrent operating lease liabilities	593	601	603
Noncurrent unearned government incentives	662	705	727
Other noncurrent liabilities	956	1,026	987
Total liabilities	21,848	20,891	20,134
Commitments and contingencies			
Shareholders' equity			
Common stock	125	124	124
Additional capital	11,564	11,217	11,036
Retained earnings	39,997	39,356	40,824
Treasury stock	(7,552)	(7,552)	(7,552)
Accumulated other comprehensive income (loss)	(264)	(260)	(312)
Total equity	43,870	42,885	44,120
Total liabilities and equity	$ 65,718	$ 63,776	$ 64,254

MICRON TECHNOLOGY, INC.
CONSOLIDATED STATEMENTS OF CASH FLOWS
(In millions)
(Unaudited)

Six months ended	February 29, 2024	March 2, 2023
Cash flows from operating activities		
Net income (loss)	$ (441)	$ (2,507)
Adjustments to reconcile net income (loss) to net cash provided by operating activities:		
Depreciation expense and amortization of intangible assets	3,839	3,863

Stock-based compensation	401	303
Provision to write-down inventories to net realizable value	—	1,430
Change in operating assets and liabilities:		
Receivables	(1,759)	2,910
Inventories	(57)	(2,896)
Other current assets	(799)	4
Accounts payable and accrued expenses	573	(1,144)
Other current liabilities	706	(638)
Other	157	(39)
Net cash provided by operating activities	2,620	1,286
Cash flows from investing activities		
Expenditures for property, plant, and equipment	(3,180)	(4,654)
Purchases of available-for-sale securities	(465)	(293)
Proceeds from maturities and sales of available-for-sale securities	726	773
Proceeds from government incentives	234	64
Other	(24)	(71)
Net cash provided by (used for) investing activities	(2,709)	(4,181)
Cash flows from financing activities		
Repayments of debt	(1,101)	(53)
Payments of dividends to shareholders	(256)	(252)
Payments on equipment purchase contracts	(82)	(76)
Repurchases of common stock - repurchase program	—	(425)
Proceeds from issuance of debt	999	5,221
Other	(18)	19
Net cash provided by (used for) financing activities	(458)	4,434
Effect of changes in currency exchange rates on cash, cash equivalents, and restricted cash	(8)	9
Net increase (decrease) in cash, cash equivalents, and restricted cash	(555)	1,548
Cash, cash equivalents, and restricted cash at beginning of period	8,656	8,339
Cash, cash equivalents, and restricted cash at end of period	$ 8,101	$ 9,887

MICRON TECHNOLOGY, INC.
NOTES
(Unaudited)
(All tabular amounts in millions)

Inventories

In 2023, we recorded charges of $1.83 billion to cost of goods sold to write down the carrying value of work in process and finished goods inventories to their estimated net realizable value ("NRV"). The impact of inventory NRV write-downs for each period reflects (1) inventory write-downs in that period, offset by (2) lower costs in that period on the sale of inventory written down in prior periods. The impacts of inventory NRV write-downs are summarized below:

	2nd Qtr.	1st Qtr.	2nd Qtr.	Six months ended	
	February 29, 2024	November 30, 2023	March 2, 2023	February 29, 2024	March 2, 2023
Provision to write down inventory to NRV	$ —	$ —	$ (1,430)	$ —	$ (1,430)
Lower costs from sale of inventory written down in prior periods	382	605	—	987	—
	$ 382	$ 605	$ (1,430)	$ 987	$ (1,430)

Income Tax

For the first quarter of 2024, we recorded tax expense based on actual first quarter results, as small changes in our projected pre-tax income cause significant changes in the estimated annual effective tax rate. With our improved fiscal 2024 outlook, we can now estimate a more reliable annual effective tax rate and have reverted to a global annual effective tax rate method. The second fiscal quarter tax benefit arises from applying this estimated annual effective tax rate to our year-to-date results.

MICRON TECHNOLOGY, INC.
RECONCILIATION OF GAAP TO NON-GAAP MEASURES
(In millions, except per share amounts)

	2nd Qtr. February 29, 2024	1st Qtr. November 30, 2023	2nd Qtr. March 2, 2023
GAAP gross margin	$ 1,079	$ (35)	$ (1,206)
Stock-based compensation	80	67	41
Other	4	5	4
Non-GAAP gross margin	$ 1,163	$ 37	$ (1,161)
GAAP operating expenses	$ 888	$ 1,093	$ 1,097
Stock-based compensation	(129)	(115)	(95)
Restructure and asset impairments	—	—	(86)
Patent cross-license agreement gain	200	—	—
Other	—	14	—
Non-GAAP operating expenses	$ 959	$ 992	$ 916
GAAP operating income (loss)	$ 191	$ (1,128)	$ (2,303)
Stock-based compensation	209	182	136
Restructure and asset impairments	—	—	86
Patent cross-license agreement gain	(200)	—	—
Other	4	(9)	4
Non-GAAP operating income (loss)	$ 204	$ (955)	$ (2,077)
GAAP net income (loss)	$ 793	$ (1,234)	$ (2,312)
Stock-based compensation	209	182	136
Restructure and asset impairments	—	—	86
Patent cross-license agreement gain	(200)	—	—
Other	2	(10)	8
Estimated tax effects of above and other tax adjustments(1)	(328)	14	1
Non-GAAP net income (loss)	$ 476	$ (1,048)	$ (2,081)
GAAP weighted-average common shares outstanding - Diluted	1,114	1,100	1,091
Adjustment for stock-based compensation	20	—	—
Non-GAAP weighted-average common shares outstanding - Diluted	1,134	1,100	1,091
GAAP diluted earnings (loss) per share	$ 0.71	$ (1.12)	$ (2.12)
Effects of the above adjustments	(0.29)	0.17	0.21
Non-GAAP diluted earnings (loss) per share	$ 0.42	$ (0.95)	$ (1.91)

(1) As described in the Income Tax note above, the second fiscal quarter tax benefit arises from applying our estimated annual effective tax rate to our year-to-date results. A portion of this benefit is included in our non-GAAP net income, with a larger benefit in our GAAP net income. The divergence between the GAAP and non-GAAP amounts of this tax benefit relates to the difference in our GAAP and non-GAAP estimated annual effective tax rates, which are computed separately.

RECONCILIATION OF GAAP TO NON-GAAP MEASURES, Continued

	2nd Qtr. February 29, 2024	1st Qtr. November 30, 2023	2nd Qtr. March 2, 2023
GAAP net cash provided by operating activities	$ 1,219	$ 1,401	$ 343
Expenditures for property, plant, and equipment	(1,384)	(1,796)	(2,205)
Payments on equipment purchase contracts	(26)	(56)	(29)
Proceeds from sales of property, plant, and equipment	13	33	17

Proceeds from government incentives	149	85	62
Investments in capital expenditures, net	(1,248)	(1,734)	(2,155)
Adjusted free cash flow	$ (29)	$ (333)	$ (1,812)

The tables above reconcile GAAP to non-GAAP measures of gross margin, operating expenses, operating income (loss), net income (loss), diluted shares, diluted earnings (loss) per share, and adjusted free cash flow. The non-GAAP adjustments above may or may not be infrequent or nonrecurring in nature, but are a result of periodic or non-core operating activities. We believe this non-GAAP information is helpful in understanding trends and in analyzing our operating results and earnings. We are providing this information to investors to assist in performing analysis of our operating results. When evaluating performance and making decisions on how to allocate our resources, management uses this non-GAAP information and believes investors should have access to similar data when making their investment decisions. We believe these non-GAAP financial measures increase transparency by providing investors with useful supplemental information about the financial performance of our business, enabling enhanced comparison of our operating results between periods and with peer companies. The presentation of these adjusted amounts varies from amounts presented in accordance with U.S. GAAP and therefore may not be comparable to amounts reported by other companies. Our management excludes the following items in analyzing our operating results and understanding trends in our earnings:

- Stock-based compensation;
- Gains and losses from settlements;
- Restructure and asset impairments; and
- The estimated tax effects of above, non-cash changes in net deferred income taxes, assessments of tax exposures, certain tax matters related to prior fiscal periods, and significant changes in tax law.

Non-GAAP diluted shares are adjusted for the impact of additional shares resulting from the exclusion of stock-based compensation from non-GAAP income (loss).

MICRON TECHNOLOGY, INC.
RECONCILIATION OF GAAP TO NON-GAAP OUTLOOK

FQ3-24	**GAAP Outlook**	**Adjustments**		**Non-GAAP Outlook**
Revenue	$6.60 billion ± $200 million	—		$6.60 billion ± $200 million
Gross margin	25.5% ± 1.5%	1.0%	A	26.5% ± 1.5%
Operating expenses	$1.11 billion ± $15 million	$123 million	B	$990 million ± $15 million
Diluted earnings per share(1)	$0.17 ± $0.07	$0.28	A, B, C	$0.45 ± $0.07

Non-GAAP Adjustments
(in millions)

A	Stock-based compensation – cost of goods sold	$ 78
A	Other – cost of goods sold	4
B	Stock-based compensation – research and development	76
B	Stock-based compensation – sales, general, and administrative	47
C	Tax effects of the above items and other tax adjustments	107
		$ 312

(1) GAAP earnings per share based on approximately 1.11 billion diluted shares and non-GAAP earnings per share based on approximately 1.14 billion diluted shares.

The tables above reconcile our GAAP to non-GAAP guidance based on the current outlook. The guidance does not incorporate the impact of any potential business combinations, divestitures, additional restructuring activities, balance sheet valuation adjustments, strategic investments, financing transactions, and other significant transactions. The timing and impact of such items are dependent on future events that may be uncertain or outside of our control.

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Micron Technology, Inc. Reports Results for the Third Quarter of Fiscal 2024

June 26, 2024 at 4:05 PM EDT

AI demand drives 50% sequential data center revenue growth and record high data center revenue mix

BOISE, Idaho, June 26, 2024 (GLOBE NEWSWIRE) -- Micron Technology, Inc. (Nasdaq: MU) today announced results for its third quarter of fiscal 2024, which ended May 30, 2024.

Fiscal Q3 2024 highlights

- Revenue of $6.81 billion versus $5.82 billion for the prior quarter and $3.75 billion for the same period last year
- GAAP net income of $332 million, or $0.30 per diluted share
- Non-GAAP net income of $702 million, or $0.62 per diluted share
- Operating cash flow of $2.48 billion versus $1.22 billion for the prior quarter and $24 million for the same period last year

"Robust AI demand and strong execution enabled Micron to drive 17% sequential revenue growth, exceeding our guidance range in fiscal Q3," said Sanjay Mehrotra, President and CEO of Micron Technology. "We are gaining share in high-margin products like High Bandwidth Memory (HBM), and our data center SSD revenue hit a record high, demonstrating the strength of our AI product portfolio across DRAM and NAND. We are excited about the expanding AI-driven opportunities ahead, and are well positioned to deliver a substantial revenue record in fiscal 2025."

Quarterly Financial Results

	GAAP(1)			Non-GAAP(2)		
(in millions, except per share amounts)	**FQ3-24**	**FQ2-24**	**FQ3-23**	**FQ3-24**	**FQ2-24**	**FQ3-23**
Revenue	$ 6,811	$ 5,824	$ 3,752	$ 6,811	$ 5,824	$ 3,752
Gross margin	1,832	1,079	(668)	1,917	1,163	(603)
percent of revenue	*26.9%*	*18.5%*	*(17.8%)*	*28.1%*	*20.0%*	*(16.1%)*
Operating expenses	1,113	888	1,093	976	959	866
Operating income (loss)	719	191	(1,761)	941	204	(1,469)
percent of revenue	*10.6%*	*3.3%*	*(46.9%)*	*13.8%*	*3.5%*	*(39.2%)*
Net income (loss)	332	793	(1,896)	702	476	(1,565)
Diluted earnings (loss) per share	0.30	0.71	(1.73)	0.62	0.42	(1.43)

Investments in capital expenditures, net(2) were $2.06 billion for the third quarter of 2024, which resulted in adjusted free cash flows(2) of $425 million. Micron ended the third quarter of 2024 with cash, marketable investments, and restricted cash of $9.22 billion. On June 26, 2024, Micron's Board of Directors declared a quarterly dividend of $0.115 per share, payable in cash on July 23, 2024, to shareholders of record as of the close of business on July 8, 2024.

Business Outlook

The following table presents Micron's guidance for the fourth quarter of 2024:

FQ4-24	**GAAP(1) Outlook**	**Non-GAAP(2) Outlook**
Revenue	$7.60 billion ± $200 million	$7.60 billion ± $200 million
Gross margin	33.5% ± 1.0%	34.5% ± 1.0%
Operating expenses	$1.19 billion ± $15 million	$1.06 billion ± $15 million
Diluted earnings per share	$0.61 ± $0.08	$1.08 ± $0.08

Further information regarding Micron's business outlook is included in the prepared remarks and slides, which have been posted at investors.micron.com.

Investor Webcast

Micron will host a conference call on Wednesday, June 26, 2024 at 2:30 p.m. Mountain Time to discuss its third quarter financial results and provide forward-looking guidance for its fourth quarter. A live webcast of the call will be available online at investors.micron.com. A webcast replay will be available for one year after the call. For Investor Relations and other company updates, follow us on X @MicronTech.

About Micron Technology, Inc.

We are an industry leader in innovative memory and storage solutions transforming how the world uses information to enrich life *for all*. With a relentless focus on our customers, technology leadership, and manufacturing and operational excellence, Micron delivers a rich portfolio of high-performance DRAM, NAND, and NOR memory and storage products through our Micron® and Crucial® brands. Every day, the innovations that our people create fuel the data economy, enabling advances in artificial intelligence (AI) and compute-intensive applications that unleash opportunities — from the data center to the intelligent edge and across the client and mobile user experience. To learn more about Micron Technology, Inc. (Nasdaq: MU), visit micron.com.

Forward-Looking Statements

This press release contains forward-looking statements regarding our industry, our strategic position, technology trends and developments including artificial intelligence, market demand, and our financial and operating results, including our guidance for the fourth quarter of 2024. These forward-looking statements are subject to a number of risks and uncertainties that could cause actual results to differ materially. Please refer to the documents we file with the Securities and Exchange Commission, including our most recent Form 10-K and Form 10-Q. These documents contain and identify important factors that could cause our actual results to differ materially from those contained in these forward-looking statements. These certain factors can be found at investors.micron.com/risk-factor. Although we believe that the expectations reflected in the forward-looking statements are reasonable, we cannot guarantee future results, levels of activity, performance, or achievements. We are under no duty to update any of the forward-looking statements to conform these statements to actual results.

(1) GAAP represents U.S. Generally Accepted Accounting Principles.

(2) Non-GAAP represents GAAP excluding the impact of certain activities, which management excludes in analyzing our operating results and understanding trends in our earnings, adjusted free cash flow, and business outlook. Further information regarding Micron's use of non-GAAP measures and reconciliations between GAAP and non-GAAP measures are included within this press release.

MICRON TECHNOLOGY, INC.
CONSOLIDATED STATEMENTS OF OPERATIONS
(In millions, except per share amounts)
(Unaudited)

	3rd Qtr.	2nd Qtr.	3rd Qtr.	Nine months ended	
	May 30, 2024	**February 29, 2024**	**June 1, 2023**	**May 30, 2024**	**June 1, 2023**
Revenue	$ 6,811	$ 5,824	$ 3,752	$ 17,361	$ 11,530
Cost of goods sold	4,979	4,745	4,420	14,485	12,511
Gross margin	1,832	1,079	(668)	2,876	(981)
Research and development	850	832	758	2,527	2,395
Selling, general, and administrative	291	280	219	834	701
Restructure and asset impairments	—	—	68	—	167
Other operating (income) expense, net	(28)	(224)	48	(267)	29
Operating income (loss)	719	191	(1,761)	(218)	(4,273)
Interest income	136	130	127	398	334
Interest expense	(150)	(144)	(119)	(426)	(259)
Other non-operating income (expense), net	10	(7)	—	(24)	(2)
	715	170	(1,753)	(270)	(4,200)
Income tax (provision) benefit	(377)	622	(139)	172	(201)
Equity in net income (loss) of equity method investees	(6)	1	(4)	(11)	(2)
Net income (loss)	$ 332	$ 793	$ (1,896)	$ (109)	$ (4,403)
Earnings (loss) per share					
Basic	$ 0.30	$ 0.72	$ (1.73)	$ (0.10)	$ (4.03)
Diluted	0.30	0.71	(1.73)	(0.10)	(4.03)
Number of shares used in per share calculations					
Basic	1,107	1,104	1,094	1,104	1,092
Diluted	1,123	1,114	1,094	1,104	1,092

MICRON TECHNOLOGY, INC.
CONSOLIDATED BALANCE SHEETS
(In millions)
(Unaudited)

As of	May 30, 2024	February 29, 2024	August 31, 2023
Assets			
Cash and equivalents	$ 7,594	$ 8,016	$ 8,577
Short-term investments	785	990	1,017
Receivables	5,131	4,296	2,443
Inventories	8,512	8,443	8,387
Other current assets	1,297	1,690	820
Total current assets	23,319	23,435	21,244
Long-term marketable investments	775	627	844
Property, plant, and equipment	37,926	37,587	37,928
Operating lease right-of-use assets	660	642	666
Intangible assets	413	414	404
Deferred tax assets	597	664	756
Goodwill	1,150	1,150	1,150
Other noncurrent assets	1,415	1,199	1,262
Total assets	$ 66,255	$ 65,718	$ 64,254
Liabilities and equity			
Accounts payable and accrued expenses	$ 5,145	$ 4,680	$ 3,958
Current debt	398	344	278
Other current liabilities	1,297	1,235	529
Total current liabilities	6,840	6,259	4,765
Long-term debt	12,860	13,378	13,052
Noncurrent operating lease liabilities	609	593	603
Noncurrent unearned government incentives	672	662	727
Other noncurrent liabilities	1,049	956	987
Total liabilities	22,030	21,848	20,134
Commitments and contingencies			
Shareholders' equity			
Common stock	125	125	124
Additional capital	11,794	11,564	11,036
Retained earnings	40,169	39,997	40,824
Treasury stock	(7,552)	(7,552)	(7,552)
Accumulated other comprehensive income (loss)	(311)	(264)	(312)
Total equity	44,225	43,870	44,120
Total liabilities and equity	$ 66,255	$ 65,718	$ 64,254

MICRON TECHNOLOGY, INC.
CONSOLIDATED STATEMENTS OF CASH FLOWS
(In millions)
(Unaudited)

Nine months ended	May 30, 2024	June 1, 2023
Cash flows from operating activities		
Net income (loss)	$ (109)	$ (4,403)
Adjustments to reconcile net income (loss) to net cash provided by operating activities:		
Depreciation expense and amortization of intangible assets	5,794	5,819
Stock-based compensation	620	448
Provision to write-down inventories to net realizable value	—	1,831

Change in operating assets and liabilities:		
Receivables	(2,562)	2,728
Inventories	(125)	(3,406)
Other current assets	(435)	(35)
Accounts payable and accrued expenses	846	(1,113)
Other current liabilities	769	(677)
Other	304	118
Net cash provided by operating activities	5,102	1,310
Cash flows from investing activities		
Expenditures for property, plant, and equipment	(5,266)	(6,215)
Purchases of available-for-sale securities	(1,110)	(496)
Proceeds from maturities and sales of available-for-sale securities	1,433	1,192
Proceeds from government incentives	267	248
Other	(35)	(90)
Net cash provided by (used for) investing activities	(4,711)	(5,361)
Cash flows from financing activities		
Repayments of debt	(1,816)	(706)
Payments of dividends to shareholders	(384)	(378)
Payments on equipment purchase contracts	(127)	(112)
Repurchases of common stock - repurchase program	—	(425)
Proceeds from issuance of debt	999	6,716
Other	(40)	—
Net cash provided by (used for) financing activities	(1,368)	5,095
Effect of changes in currency exchange rates on cash, cash equivalents, and restricted cash	(15)	(13)
Net increase (decrease) in cash, cash equivalents, and restricted cash	(992)	1,031
Cash, cash equivalents, and restricted cash at beginning of period	8,656	8,339
Cash, cash equivalents, and restricted cash at end of period	$ 7,664	$ 9,370

MICRON TECHNOLOGY, INC.
NOTES
(Unaudited)
(All tabular amounts in millions)

Inventories

In 2023, we recorded charges of $1.83 billion to cost of goods sold to write down the carrying value of work in process and finished goods inventories to their estimated net realizable value (“NRV”). The impact of inventory NRV write-downs for each period reflects (1) inventory write-downs in that period, offset by (2) lower costs in that period on the sale of inventory written down in prior periods. The impacts of inventory NRV write-downs are summarized below:

	3rd Qtr.	2nd Qtr.	3rd Qtr.	Nine months ended	
	May 30, 2024	February 29, 2024	June 1, 2023	May 30, 2024	June 1, 2023
Provision to write down inventory to NRV	$ —	$ —	$ (401)	$ —	$ (1,831)
Lower costs from sale of inventory written down in prior periods	—	382	281	987	281
	$ —	$ 382	$ (120)	$ 987	$ (1,550)

Income Tax

In the first quarter of 2024, our tax expense was based on actual results for jurisdictions where small changes in our projected pre-tax income would have caused significant changes in the estimated annual effective tax rate. With our improved fiscal 2024 outlook, we were able to estimate a more reliable annual effective tax rate and have reverted to a global annual effective tax rate method for all jurisdictions beginning in the second quarter of 2024.

MICRON TECHNOLOGY, INC.
RECONCILIATION OF GAAP TO NON-GAAP MEASURES
(In millions, except per share amounts)

	3rd Qtr. May 30, 2024	2nd Qtr. February 29, 2024	3rd Qtr. June 1, 2023
GAAP gross margin	$ 1,832	$ 1,079	$ (668)
Stock-based compensation	80	80	60
Other	5	4	5
Non-GAAP gross margin	$ 1,917	$ 1,163	$ (603)
GAAP operating expenses	$ 1,113	$ 888	$ 1,093
Stock-based compensation	(137)	(129)	(91)
Restructure and asset impairments	—	—	(68)
Patent cross-license agreement gain	—	200	—
Litigation settlement	—	—	(68)
Non-GAAP operating expenses	$ 976	$ 959	$ 866
GAAP operating income (loss)	$ 719	$ 191	$ (1,761)
Stock-based compensation	217	209	151
Restructure and asset impairments	—	—	68
Patent cross-license agreement gain	—	(200)	—
Litigation settlement	—	—	68
Other	5	4	5
Non-GAAP operating income (loss)	$ 941	$ 204	$ (1,469)
GAAP net income (loss)	$ 332	$ 793	$ (1,896)
Stock-based compensation	217	209	151
Restructure and asset impairments	—	—	68
Patent cross-license agreement gain	—	(200)	—
Litigation settlement	—	—	68
Other	3	2	7
Estimated tax effects of above and other tax adjustments[1]	150	(328)	37
Non-GAAP net income (loss)	$ 702	$ 476	$ (1,565)
GAAP weighted-average common shares outstanding - Diluted	1,123	1,114	1,094
Adjustment for stock-based compensation	13	20	—
Non-GAAP weighted-average common shares outstanding - Diluted	1,136	1,134	1,094
GAAP diluted earnings (loss) per share	$ 0.30	$ 0.71	$ (1.73)
Effects of the above adjustments	0.32	(0.29)	0.30
Non-GAAP diluted earnings (loss) per share	$ 0.62	$ 0.42	$ (1.43)

(1) The second fiscal quarter tax benefit arose from applying our estimated annual effective tax rate to our year-to-date results. A portion of this benefit is included in our non-GAAP net income, with a larger benefit in our GAAP net income. The divergence between the GAAP and non-GAAP tax relates to the difference in our GAAP and non-GAAP estimated annual effective tax rates, which are computed separately.

RECONCILIATION OF GAAP TO NON-GAAP MEASURES, Continued

	3rd Qtr. May 30, 2024	2nd Qtr. February 29, 2024	3rd Qtr. June 1, 2023
GAAP net cash provided by operating activities	$ 2,482	$ 1,219	$ 24
Expenditures for property, plant, and equipment	(2,086)	(1,384)	(1,561)

Payments on equipment purchase contracts	(45)	(26)	(36)
Proceeds from sales of property, plant, and equipment	41	13	34
Proceeds from government incentives	33	149	184
Investments in capital expenditures, net	(2,057)	(1,248)	(1,379)
Adjusted free cash flow	$ 425	$ (29)	$ (1,355)

The tables above reconcile GAAP to non-GAAP measures of gross margin, operating expenses, operating income (loss), net income (loss), diluted shares, diluted earnings (loss) per share, and adjusted free cash flow. The non-GAAP adjustments above may or may not be infrequent or nonrecurring in nature, but are a result of periodic or non-core operating activities. We believe this non-GAAP information is helpful in understanding trends and in analyzing our operating results and earnings. We are providing this information to investors to assist in performing analysis of our operating results. When evaluating performance and making decisions on how to allocate our resources, management uses this non-GAAP information and believes investors should have access to similar data when making their investment decisions. We believe these non-GAAP financial measures increase transparency by providing investors with useful supplemental information about the financial performance of our business, enabling enhanced comparison of our operating results between periods and with peer companies. The presentation of these adjusted amounts varies from amounts presented in accordance with U.S. GAAP and therefore may not be comparable to amounts reported by other companies. Our management excludes the following items in analyzing our operating results and understanding trends in our earnings:

- Stock-based compensation;
- Gains and losses from settlements;
- Restructure and asset impairments; and
- The estimated tax effects of above, non-cash changes in net deferred income taxes, assessments of tax exposures, certain tax matters related to prior fiscal periods, and significant changes in tax law.

Non-GAAP diluted shares are adjusted for the impact of additional shares resulting from the exclusion of stock-based compensation from non-GAAP income (loss).

MICRON TECHNOLOGY, INC.
RECONCILIATION OF GAAP TO NON-GAAP OUTLOOK

FQ4-24	**GAAP Outlook**	**Adjustments**		**Non-GAAP Outlook**
Revenue	$7.60 billion ± $200 million	—		$7.60 billion ± $200 million
Gross margin	33.5% ± 1.0%	1.0%	A	34.5% ± 1.0%
Operating expenses	$1.19 billion ± $15 million	$125 million	B	$1.06 billion ± $15 million
Diluted earnings per share(1)	$0.61 ± $0.08	$0.47	A, B, C	$1.08 ± $0.08

Non-GAAP Adjustments
(in millions)

A	Stock-based compensation – cost of goods sold	$ 84
A	Other – cost of goods sold	4
B	Stock-based compensation – research and development	77
B	Stock-based compensation – sales, general, and administrative	48
C	Tax effects of the above items and other tax adjustments	315
		$ 528

(1) GAAP earnings per share based on approximately 1.12 billion diluted shares and non-GAAP earnings per share based on approximately 1.14 billion diluted shares.

The tables above reconcile our GAAP to non-GAAP guidance based on the current outlook. The guidance does not incorporate the impact of any potential business combinations, divestitures, additional restructuring activities, balance sheet valuation adjustments, strategic investments, financing transactions, and other significant transactions. The timing and impact of such items are dependent on future events that may be uncertain or outside of our control.

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