John Kelly, senior vice president and group executive of the IBM technology Group claims that, “High tech companies are turning to IBM for their high technology needs. The semiconductor industry has never been stronger …We are investing billions of dollars across the globe to meet the long term technology needs of our customers.” To prepare for future market demand, IBM recently invested over $2.5 billion in its East Fishkill N.Y. semiconductor facility to manufacture advanced integrated circuit chips.

The plant is being built to produce the new industry standard 300mm wafers containing chips for a range of products from cellular phones to home video game consoles. The company expects the facility to contribute to the $4.8 billion dollar revenue projections for IBM Microelectronics, the company’s chip making and selling arm. The East Fishkill plant is meant to be a fully automated state of the art, hands off production facility. In order for the plant to succeed, IBM knows it will have to take a whole new approach to semiconductor manufacturing while enhancing the company wide capability of increasing consumer responsiveness and efficiency.

The Semiconductor Industry

Semiconductor manufacturing is a capital-intensive business characterized by dynamic market conditions, disruptive technologies and cyclical sales. A market driven business, semiconductors are frequently designed to meet specific customer requirements. Production time is long, ranging from 12-52 weeks for delivery of the final product. Firms that can anticipate customer demand and have the right devices in volume will have a significant differential advantage in satisfying customers. Thus the ability of a firm to forecast and respond to customer demand is a key factor to achieving success.

Today, the semiconductor industry is undergoing unprecedented changes. Technology challenges are escalating as the potential for scaling decreases. As Research & Development (R&D) and manufacturing investment requirements increase, the ability of many firms to compete is becoming unaffordable. As such the increasing cost of doing business is causing liquidations, consolidations and a growth in strategic alliances. Such factors are leading to manufacturing firms moving offshore and contributing to the growth of large-scale semiconductor foundries overseas.

After three years of stagnant revenues, the semiconductor industry is expecting sales to reach the levels achieved in 2000. The increase in smart gadgets used in toys, automobiles, household products and electronics is expected to reenergize the demand for chips. SEMCO research predicts that revenue in the global semiconductor industry will...
grow approximately 26.8%. Semiconductor manufacturers are running at full or nearly full capacity, as customers are double booking orders in fear of potential shortages.

The Bureau of Labor Statistics reports that the semiconductor industry employs a domestic workforce of approximately 226,000. In 2003, the semiconductor industry manufactured about 90 million transistors for every man, woman and child on Earth, and by 2010, this number should be 1 billion transistors. U.S.-based semiconductor manufacturers are located all over the world, including approximately 70 fabrication facilities in the U.S. and 68 in foreign countries with 5-8 of these in China.

The semiconductor industry is very volatile and marked by intense rivalries among individual companies, creating pressure on chip manufacturers to come up with more innovative and performance products. That pressure to be responsive to market needs extends to chip equipment makers, foundries, design labs, distributors -- everyone else in the queue that is responsible for bringing chips from the engineering benchtop to various applications. The largest chip company is Intel, while Advanced Micro Devices (AMD) is a distant second. The top ten semiconductor manufacturers ranked by sales includes:

1. Intel
2. Samsung Electronics
3. Renesas
4. Texas Instruments
5. Toshiba
6. STMicroelectronics
7. Infineon Technologies
8. NEC
9. Freescale Semiconductor
10. Philips Semiconductors

Many chip makers, including some of these giants, have begun to outsource more and more of their production. Cutting-edge chip production is hugely expensive, and building a new fabrication plant has become prohibitive. Increasingly, companies in the semiconductor industry are relying on foundries, dedicated contract manufacturers whose focus on the physical production of chips allows them to sustain the massive investments needed to keep up with the latest in manufacturing technology. The field was pioneered by Taiwan Semiconductor, but dominated by United Microelectronics, while IBM is the largest U.S.-based foundry service. Appendix 1 lists total worldwide sales and market share figures for the past ten years.

**IBM Microelectronics**

IBM is the world's largest information technology company. Measured by revenue, IBM is the biggest provider of IT services ($43B), hardware ($28B) and rental and financing ($3B). 2003 revenues were $89B. The Microelectronics Division develops, manufactures, and markets state-of-the-art semiconductor, packaging and interconnectivity products, network technology services and solutions to customers worldwide. The division manufacturing locations are in Austin, TX; Burlington, VT; East Fishkill, NY; Endicott, NY; Raleigh, NC; Waltham, MA; Canada; Ireland; Japan; France; Singapore, and other locations worldwide.
East Fishkill Semiconductor Manufacturing Facility

Designing and manufacturing multimillion-gate integrated chips that meet the demands of today’s powerful products is a complicated, expensive and time-consuming process. IBM Integrated circuit design methodologies, tools and services are employed to simplify the manufacturing process. The key to success is to get the designs right the first time, with efficiency and flexibility that exceeds industry standards.

Semiconductor manufacturing is a multi-stage process (see figure 1), which includes wafer fabrication, semiconductor fabrication, and assembly/packaging. First a thin silicon wafer, and consecutive layers of integrated circuitry (ICs) are built up, one on top of another, to produce a single completed wafer. Semiconductors must be manufactured in a highly controlled and clean environment.

A series of masking and diffusion processes are repeated up to twenty times using the various patterns necessary to create a particular type of IC. Masking involves the transfer of an intricate pattern by exposing unmasked portions of the wafer to light. Then, during diffusion, electrically charged particles are implanted into the silicon to alter its electrical characteristics. This forms negative and positive conducting areas, creating a pathway through which electricity can flow. Finally, during assembly and packaging, the wafers are cut into individual ICs that are then mounted into a package for assembly on a printed circuit board.

A major activity that a semiconductor automation framework has to provide is the control of the fabrication process as a wafer undergoes several steps in fabrication. The fabrication process is plagued by a variety of factors including: equipment aging, variability of consumables, and fluctuating conditions. Performance may also change as the result of routine maintenance operations. The manufacturing information system needs to keep track of the state of a wafer as it moves through the facility and carry out appropriate actions to maintain the overall quality of the fabrication. The automation system, not only specifies and initiates the process, but it also makes provisions for continuous process upgrades depending upon the manufacturing conditions.
The figure highlights the stages in which the containers are transported through the plant.

2 The figure highlights the stages in which the containers are transported through the plant.
A key factor in the production of semiconductor manufacturing is turnaround time (TAT). Because of the ever-increasing complexity of semiconductor manufacturing, a 30% reduction in TAT simply keeps the development time at a constant level in the evolution from one technology node to the next, with the common objective to decrease TAT and to reduce the overall development time. TAT for simple to more complex designs range from several to over 60 days. The TAT for any process is determined by:

1. The number of steps in the design flow
2. The number of iterations for each step
3. The run time of each step
4. The hold time between each step

The production transfer process between stages of semiconductor manufacturing requires the use of several different containers. First wafers travel to/from the facility in a shipping container and are transported between process equipment with process container. Lithography equipment uses a different container for transporting receptacles.

The process of wafer production requires that there is thousands of each container active at any time during a production shift. The containers are transferred between many process tools and storage areas by the Automated Material Handling System (AMHS). Finally, containers are transferred between several manufacturing facilities. Such a process requires a common container tracking methodology be used which is able to identify the location of all products at all times.

Containers for semiconductor manufacturing exist in three forms. All external wafer shipments take place in a front opening-shipping box (FOSB). The FOSB is designed to protect silicon wafers during transportation and insure a clean and secure environment. Wafers transported within the factory travel by way of a front opening unified pod (FOUP), which is designed to protect and transport silicon wafers across process tools.

![FIGURE 2](image1.png)  ![FIGURE 3](image2.png)
Finally, a standard mechanical interface (SMIF) is utilized during the coating and exposure stage with a RSP container, which is standardized across the semiconductor industry.

**FIGURE 4**
SMIF RETICLE POD

Each carrier, as well as the wafers inside, needs to be tracked continuously as it moves down the production line, which allows employees to monitor the status of a wafer at any stage in the production process. This helps prevent mistakes and allows better inventory control as well as customer service, because employees can easily get product status reports in real time and pass update information on to customers whenever they call. “Instead of worrying about the logistics, employees should focus on making chips and meeting our customers’ demands,” notes Ed Sherwood, advisory engineer, Automated Material Handling Systems, IBM.

Current manufacturing facilities for 200mm wafers can be improved substantially along a number of dimensions including supplying more accurate information that will improve the ability of the firm to meet customer demand, increasing forecast accuracy to reduce finished goods in inventory, and developing a more flexible manufacturing plan. Driven by the need to increase productivity, the semiconductor industry has begun to explore the possibility of developing 300mm wafers.

Sematech was formed as an industry and government consortium to leverage resources, share risks and solve common manufacturing problems in the semiconductor industry. At the forefront of research and development of new technology, including the development of wafers and wafer handling procedures, Sematech lets competitors leverage knowledge across the semiconductor industry, to advance the knowledge and practice of semiconductor manufacturing. Sematech’s role is to designed as a pre-competitive environment to define semiconductor technology standards and infrastructure needs for the industry. The international 300mm initiative was formed as a subsidiary of Sematech to cooperate on developing tool standards and specifications. The industry realized that with a larger wafer size to increase product output, a cascading impact occurs on the
accompanying manufacturing infrastructure. Sematech helped address the changes needed to improve the semiconductor-manufacturing infrastructure, including new tools, technology, and processes to accommodate the increase in wafer size to 300mm.

In order for the new Fishkill facility to succeed, IBM realizes it will have to take a whole new approach to semiconductor manufacturing. The facility is designed to be a completely automated, “hand offs” manufacturing facility for 300 mm wafers.

A hands-off product-tracking system needed to be developed to support the automated production and real time product inventory capabilities IBM wanted its new operation to have. For example, in existing semiconductor manufacturing facilities, production line employees read labels on wafer carriers to determine where they belong, and physically move the carriers to their designated production tool stations. Afterwards, the employees have to make sure that the assortment of wafers inside each carrier is processed properly. IBM needed to re-engineer its labor-intensive production process and find a way to respond to customers’ demands for timely product status updates. To accomplish this goal, a system needed to be designed which integrates technologies to automate the routing of wafers through each fabrication station.

**Automatic Identification**

Automatic identification is the broad term given to a host of technologies that are used to help machines identify objects. Auto-identification is often coupled with automatic data capture. That is, companies want to identify items, capture information about them and upload the data into a computer without manual intervention. The aim of most auto-ID systems is to increase efficiency, reduce data entry errors, and free up staff to perform more value-added functions, such as providing customer service. There are a host of technologies that fall under the auto-ID umbrella, including bar codes, smart cards, and voice recognition, some biometric technologies (e.g. retinal scans), optical character recognition, and radio frequency identification (RFID).

RFID and bar codes are two different technologies but with applications, that sometimes overlap. The big difference between the two is bar codes are line-of-sight technology requiring an employee to "see" the bar code to read it. RFID, by contrast, doesn’t require line-of-sight, and can be read as long as the transmitter is within range of a reader. Bar codes have other shortcomings as well. If a label is ripped, soiled or falls off, there is no way to scan the item. And standard bar codes identify only the manufacturer and product, not the unique item.

A large organization like IBM can tap resources from within the company. IBM research has over 50 patents that relate to automatic identification technologies. “IBM is rapidly expanding into industrial markets, where RFID is highly successful in tracking manufacturing and work-in-process, locating high-value assets and improving supply chain operations.” – Faye Holland, Worldwide RFID leader, IBM Global Services
RFID technologies work by storing unique serial identification numbers for people, objects or information on a microchip attached to an antenna. The microchip and antenna act as a transponder transmitting information to a reader. A package encases the chip and antenna making a tag that can be attached to a physical object. The reader then converts the radio waves from the tag into digital information that can be communicated electronically to key stakeholders. Although RFID is a proven technology which has been around since the early 70s, it has until recently been extremely costly to implement, limited in its practical applications and lacking a standard set of communication protocols.

In the past, firms have employed the technology to monitor product flow within the four walls of a facility. The technology has only recently been expanded to address issues surrounding the integrated supply chain.

Although more expensive than traditional bar codes, RFID does not require line-of-sight for effective reading and transfer of information. For example, bar codes require the physical alignment of a scanner to read the bar code either manually or automatically. Conversely, RFID tags can be read as long as they are within the range of a reader. The reading range for RFID tags depend on a number of factors including frequency, power of the reader, interference from metal objects or other RFID devices. High frequency tags allow transmission reading within a range of 3 feet, while ultra high frequency (UHF) permits readings from 10-20 feet. When UHF tags are boosted by additional battery power the transmission reading range increases to over 300 feet.

All sorts of objects can be tagged using RFID technology, including pallets, cases, trays, or individual items. RFID tags can be read-write or read-only. A read-write chip allows firms to add information to tags as they move through the supply chain. Firms may also write over existing information. Obviously, read-only RFID tags allow information to be written on the chip only once.

In addition to the reading range advantage, RFID tags possess additional advantages over bar codes. Table 1 provides a comparison of barcode versus RFID technology.
Today there are six types of RFID tags classified as active or passive tags. These passive tags form the basis of the Auto-ID designs, and, if manufactured in billions, will eventually come down in price from $0.80 to $0.05 in the next 2 years.

Class 0 and class 1 RFID tags are passive with different communication protocols. Passive tags have only read-only or write-once capability when used to identify products. Semi-passive RFID tags use a battery to communicate with readers but also draw power from the reader to operate. Finally active RFID tags operate with a self-operating battery source, enabling the chip to broadcast signals to a reader. Active and semi-passive RFID tags (Classes 2-5) have added functionality that allows object’s to be scanned over a greater distance, and store/transmit greater amounts of information.

The adoption of RFID technologies and integrating their use across the supply chain are not easy tasks. They and present a number of challenges that firms must address for the effective implementation of RFID technology. Table 2 provides an overview of some of the challenges that firms face.
TABLE 2
RADIO FREQUENCY IDENTIFICATION CHALLENGES

<table>
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<th>RFID Challenges</th>
<th>System Challenges</th>
<th>Operational Challenges</th>
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<tr>
<td>Reader detection rates, ranges, and dwell time</td>
<td>Availability of data both internally and externally</td>
<td>Site readiness to adopt new challenges</td>
</tr>
<tr>
<td>Type of product (i.e., metals, liquids)</td>
<td>Access to public and private EPC data both internally and externally</td>
<td>Learning curve of new technology</td>
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<tr>
<td>Read penetration (e.g., middle of pallet, etc.)</td>
<td>Hardware integration (e.g., conveyor/sorters, RF terminals, etc.)</td>
<td>Product/tag associations (i.e., pallet, case)</td>
</tr>
<tr>
<td>Type (i.e., active, passive), frequency, number, and location of tags</td>
<td>Software integration and modification</td>
<td>Managing the “twilight period” between barcode and RFID adoption</td>
</tr>
<tr>
<td>Number, placement, and power of readers</td>
<td>EPC data warehousing</td>
<td></td>
</tr>
<tr>
<td>Reading of adjacent product</td>
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</table>

While international standards currently exist for tracking animals, there is no global standard for tracking goods through the supply chain. The electronic product code (EPC) is being developed as common language for RFID technologies. The EPC code is an open standard based system that facilitates collaboration between partners in the value chain. Figure 6 illustrates the current state of the EPC code.

FIGURE 6
ELECTRONIC PRODUCT CODE
RFID is expected to be a powerful enabling technology that when coupled with process change, will help transform today’s supply chain operations by improving efficiency, productivity, and reducing costs. Improved visibility of data and access to information will enable benefits across the integrated supply chain.

As of today, the EPC-based implementations are in the proof of concept phase or are being field tested, in various stages of the supply chain. The evolution of the EPC code will first have to occur with the four walls of supply chain stakeholders, before moving to integrate processes across the supply chain.

Costs and Benefits of RFID Technology

For example distribution center productivity can be increased by 5-15%, while inventory and shipping accuracy is approaching 100%. Effective use of RFID technology will also lead to
- Identification of diverted products
- Reduced counterfeiting
- Improved and accurate product recall
- Reduced write offs due to product returns
- Improved product availability
- Faster replenishment of inventory
- Better product information

Supply chain and logistics benefits include: 1) reduced costs due to increased automation 2) easier inventory management 3) improve response times 4) increased tracking accuracy; and, 5) improved security.

The readers and sensors used to read the information are comparable in cost to the components of a typical EM or RF theft detection system, typically: $2,500 to $3,500 or more each; a server costing as much as $15,000 may be required; and the tags cost $.60 to $.85 each. It may be some time before the cost of tags comes down to $.50 or less. Industry analysts predict that typical, large-scale manufacturers will spend from $9 million to $25 million on RFID technology. RFID investments can grow considerably as more advanced capabilities are pursued.

The cost for equipment and/or engineering work around the placement of readers and tagging equipment throughout the plant floor and warehouse could be significant if more seamless integration is desired with conveyors, portals and transporting vehicles. The cost for specialized, network-connected tagging apparatus offered by various suppliers, including plant floor machinery manufacturers, could be significant if these specialized apparatus are desired. In addition to initial investment costs associated with RFID
implementations, companies will also have recurring costs, depending on such factors as the product life of the tag and whether RFID tags can be used more than once.

The recurring costs for tags will vary greatly between companies. The recurring cost for technology maintenance for RFID components and related infrastructure is typically 15 to 20 percent of the acquisition cost.

Recent industry reports that with the use of RFID, companies can expect distribution productivity to increase 5-10% and their ability to track inventory and product shipping accuracy will approach 100%. “The value of RFID increases, as you go from tagging pallets to cases to individual units.” Adel Al-Saleh, IBM's general manager of global wireless of e-business believes, "The [economic] environment is forcing companies to look inside of their organizations to see where they can take cost out and how they can be more productive, how they can reach operational excellence. RFID is one of those key technologies that allow companies to achieve operational excellence."
The Case Assignment

Your team has been presented with the challenge of developing an evaluation and recommendation of whether the IBM Fishkill facility should adopt RFID as the solution for tracking semiconductor wafers through the plant and how the plan should be implemented.

While RFID appears to be the obvious choice as a solution to address the hands-off product tracking requirements of the new automated Fishkill facility, the business case for its adoption needs to be developed. The business case entails articulating the financial benefits to be achieved through the manufacturing process changes, identifying improvements in current product tracking processes, and analyzing the implications of any process changes.

At a minimum, executives expect a managerial level presentation in six weeks to address the following issues:

1. How can the manufacturing operations at East Fishkill use automatic identification technology to reduce manufacturing costs and increase material throughput?
2. Where and how would automatic identification technology (manufacturing, distribution, logistics, etc.) be applied given a cost-benefit analysis?
3. How would automatic identification be applied? Specify the supply chain tasks or processes to be enabled, including expected areas of improvements that can be measured empirically (e.g., inventory turns, TAT, labor cost, etc.).
### APPENDIX 1

**Total Semiconductor World Market Sales & Shares (in Millions/ $)**

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