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The Spectrum of Risk Management in a Technology Company

## Assessing and Managing Asset Loss from Hazard Risks

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## ABSTRACT

Risks to physical assets from hazard events are omnipresent. Hazard risks include perils such as fire, explosions, floods, windstorms, earthquakes, typhoons, etc.

Intel has unique risks related to clean room environments: it runs an ultra-clean, pristine work environment with sensitive, specialized high-value equipment, producing high volumes of product at nano geometries with uncompromising quality.

The Risk Management Process for hazard risk evaluation is a disciplined approach that consists of identification, control, transfer, and mitigation. In this paper we describe how this process is applied with exceptional results in establishing specific studied controls to address the hazards of fire, flood, and windstorm. The result is the mitigation of the consequences of these risks within semiconductor manufacturing facilities. Combined with the Business Continuity and Emergency Response programs addressed elsewhere in this issue of the *Intel Technology Journal*, this hazard identification and mitigation process reflects one of the crucial pieces of an integrated approach to managing operational risks. Challenges and solutions are discussed.

While we define the role of risk transfer and mitigation in the overall Risk Management Process, the focus of this paper is on the identification, analysis, and control of hazard loss risks.

## INTRODUCTION

Risk of loss can come from many sources. Clean room environments used in semiconductor manufacturing offer specific challenges to create best-in-class fire protection and property loss control. Intel has taken a leadership role in developing and applying the appropriate balance of passive and active control measures to reduce loss from catastrophic hazard risks in its facilities and clean rooms. Processes are established to identify, quantify, and

implement appropriate levels of property loss control or damage-limiting controls for buildings.

The hazard risk of fire within semiconductor industry clean rooms was the leading cause of large and often catastrophic loss events prior to 1999. Facilities affected by fire and smoke were often unusable for years due to the latent issues related to particulates generated as by-products of combustion that compromised the clean room environment. Intel Risk Management understood the importance of taking the lead in finding solutions to identify fire scenarios, quantify the impacts, and develop and implement control mitigation as an integral part of the corporate property insurance program cost management and overall business continuity.

Loss investigations of catastrophic fires determined the root cause and identified the various elements that lead to uncontrolled events. In nearly all of the large fires that were investigated, the combustible materials used in process tools were identified as the main contributor to small fires that developed into catastrophic fires. A process of risk identification and control was used to develop a detailed understanding of failure mechanisms, assess both passive and active control solutions, and to determine a long-term strategy for implementing non-fire propagating materials solutions within process tools.

Windstorm and flood hazards are present in many geographic locations where Intel conducts manufacturing. The data to determine flood and wind speed exposures to buildings and structures may not be available in many geographic areas. Even when flood and wind speed maps exist, they may not provide the specific details needed for site location exposure analysis. Risk Management reviews insurance industry data of windstorm losses to roofing systems and evaluates what roof and wall systems perform well from a property loss control perspective in severe hurricanes and typhoons. A process has been established to implement appropriate property loss control by performing site-specific evaluations of Intel locations, determining the appropriate controls required for new buildings, and looking at when to implement potential

improvements to existing buildings through existing Intel processes.

## **RISK MANAGEMENT PROCESS**

The Risk Management Process has four elements: identification, control, transfer, and mitigation. Risk identification is a means of categorizing risks and perils in order to baseline the measurement of impact relative to a loss event or scenario. Control measures are engineering applications of passive and/or active means to avoid or mitigate a loss exposure. Risk transfer can be achieved through contract terms management where applicable, or through insurance contracts. Mitigation includes a diligent claims management process to minimize the cost/impact of a loss. In this paper we discuss two of the four elements: the identification and control process.

### **Identification**

Risk of property loss can be categorized into common perils: hazards or activities that cause a loss. Losses from these perils are quantified by measuring the severity of their financial impact. Loss data can cluster the frequency of events. The data should include both events within the company and also reported losses from within the industry via public information sources. Various loss modeling tools can be utilized such as Risk Maps, Risk Impact and Likelihood Matrices, FMEA studies, etc.

One tool Intel Risk Management uses is a detailed quantification study method called an Intel Loss Scenario, or ILS, that develops very specific hypothetical event parameters and consequences in the facility. The event selected is often a fire and is based on results of fire science research and/or external loss histories. The extent of the loss within a facility is then modeled to quantify the resulting financial impact for both physical damage and business interruption. Included in the analysis is the mitigation resources identified from credible business continuity plans. The goal of this table-top exercise is to quantify and measure a specific loss caused by a perilous event and to determine a baseline for what a relative level of risk might be for other loss scenarios.

### **Acceptable Level of Loss**

Determining an acceptable level of loss is often the most difficult task, as each stakeholder can have a different value amount or metric for loss. A threshold needs to be established to determine what if any risk control should be applied to identify events from both a frequency and severity perspective. Analysis is required to then evaluate the implementation capability and cost for control mitigation options, focused on prioritizing resources needed to achieve the desired result.

## **Risk Control**

Based on risk identification and quantification results, control measures can be evaluated to determine the appropriate implementation to mitigate the loss exposure. Normally the initial focus is on high-severity and moderate-to-high-frequency events; however, identification may highlight simple and inexpensive control measures that do not require appreciable resources to implement. There are two protection methods for controlling risk: passive and active. Passive protection does not require a system activation (mechanical or electrical) to achieve the desired result. An example of a passive system is a firewall within a building that is designed and built to a specific requirement based on the building occupancy. A properly designed and installed firewall limits fire spread within a building without the need for a system to activate. The cost of passive systems is often incurred upfront during initial construction. Maintenance costs thereafter are usually limited to periodic evaluation of the physical condition of the system.

Active protection requires a system to be activated (normally mechanical or electrical) to achieve the desired result. These systems are therefore not as inherently reliable as passive systems as most are not inherently fail-safe. In the example of the firewall, any unprotected doors or other openings needed for building functionality require rated doors or fire shutters to operate or close properly to ensure the integrity of the containment design. A door that does not close due to an obstruction would defeat the purpose of the entire control system.

Active controls are often times included in emergency preparedness planning and business continuity plans. These programs are critical to reducing losses from all events, not just hazardous ones. They are actively initiated, managed, and require periodic review to ensure they address current business operations.

The costs of active systems are incurred in development or in initial system installation and continue over time. These on-going costs are generally higher than those for sustaining passive controls, and they include hardware, controls, monitoring, acceptance testing, and periodic testing and maintenance of the systems.

## **Risk Transfer**

Once a hazard risk is identified, assessed, and quantified, a decision should be made on how to manage that exposure from a financial aspect: is this a risk exposure that the corporation should transfer to a third party via insurance or another financial tool (e.g., a catastrophe bond); is this an exposure that can be transferred via contract to a third party, (i.e., getting a vendor to accept

Risk of Loss or damage to Intel goods in transit); or ultimately, is this an exposure that the corporation should insure against or fund, such as earthquakes? Earthquake insurance is expensive to purchase and is limited in coverage with a percentage of loss deductible that makes the coverage unattractive.

The reality is that there are insurance market limitations and complexities that must be addressed: not every insurance carrier is interested in underwriting technology clean room environments, for instance. Intel must develop a strategy around what hazard risks should be insured. It would then need to determine what the appropriate deductibles should be, what the optimum levels of overall insurance limits should be, and what form of insurance should be purchased.

If insurance is to be purchased, the corporation's risk profile has to be marketed to the right insurance partners, and the best premiums negotiated. Another limitation is that Intel's size is such that there is no single insurer that is capable of absorbing a significant loss in our factory network: Intel must syndicate its insurance program among many different insurers. Our Property Insurance Program, for instance, comprises 20 different insurers from different countries including: Britain, Germany, Bermuda, America, and Japan.

### **Mitigation**

An often overlooked portion of the Risk Management continuum is Risk Mitigation via aggressive Claims Management. Just as post-loss planning through a thorough Business Continuity (BC) plan is essential to getting the business operations back up and running as quickly as possible, having a well-planned strategy and process for making a recovery from a loss caused by vendor or supplier liability within the supply chain is just as critical. In most cases, you will need to recover losses from another party's insurance carrier, but in some cases, there will be no insurance money available. This strategy involves many internal players, facilities groups, business divisions, and legal, financial, and risk management groups.

The claims mitigation process is tedious and disciplined: a claim must be investigated, analyzed, documented, and negotiated to support any recovery, whether it is from an insurer or a contractual partner. The time line from the date of loss to closure often spans several quarters and could last over several years. Depending on the complexity of the claim, legal and forensic accounting specialists may be required.

### **Results**

Semiconductor industry loss history shows fires within clean rooms cause the largest losses. Despite industry

clean-room fire losses that have affected numerous companies, Intel has not had a significant loss in over three decades. Risk Management championed hazard identification, modeling, and control processes for the fire hazard risk perils that led to the development and implementation of a best-in-class process called the Combustible Material Management Program (CMMP). Risk Management maintains results through efficient partnering with existing stakeholder processes. This program is embedded in the technology development material selection process within the clean room envelope that includes tools and support infrastructure. These successes are effectively proliferated to high-volume manufacturing (HVM) sites through "copy exactly" controls to manage these location exposures.

Intel has sites in geographic location where buildings have been exposed to significant natural hazard events such as windstorms and flooding. These include Hurricane George in 1998 that affected the facility in Las Piedras, Puerto Rico; and most recently, Typhoon Xangsane (also known as Milenyo) in September 2006 that affected Cavite in the Philippines. Implementing effective wind resistive roof and wall fastening controls based on previous loss analysis studies, and having well-developed emergency response plans for typhoon and flooding mitigated serious damage to Intel operations at these sites.

The diligent Risk Management Process approach has resulted in recoveries for various losses over the last five years of over \$11M. When benchmarked against a national indicator of various industries for Cost of Risk (COR) (premiums + expenses + losses) as compiled by the Risk and Insurance Management Society, Intel maintains one of the lowest COR levels.

## **FIRE EXPOSURE WITHIN CLEAN ROOMS**

### **Fire Science Basics**

When evaluating fire hazards, the elementary fire triangle principal is used to evaluate this risk. In order for fire to occur, three elements need to be present: fuel, a source of ignition, and sufficient levels of oxygen. Not quite rocket science! In common environments, removing any one of these three elements will prevent a fire. When applying the fire triangle principal to identify hazards within process tools, each element offers unique challenges.

The fabrication process often requires the use of flammable or combustible chemicals. In addition to process chemistries, the tools themselves require non-corrosive or non-reactive construction materials to allow for the high-yield fabrication of wafers. Using noncombustible chemicals or tool construction materials

can eliminate the fire risk from the fuel leg of the fire triangle.

Ignition sources from electrical sources are controlled in normal operations. Static electricity sparks are controlled through normal grounding. However, investigation of loss events and subsequent research testing indicate electrical component failures are the most prevalent ignition sources. Electrical devices used to heat acid chemicals in the process tools fail over time, as they are in areas of the tool that are subject to corrosive environments and are in concealed spaces. Removing electrical ignition sources in areas where combustible materials exist in oxygen atmospheres can eliminate fire risk from the ignition leg of the triangle.

The clean-room environment requires high airflow and filtration over process tools to ensure clean environments for processing wafers, and to exhaust chemical vapors resulting from the processing. Common gaseous fire suppression systems that reduce oxygen concentrations below levels to support combustion include carbon dioxide, nitrogen, or other inert gas mixtures. Although these systems could be effective in eliminating the fire risk, reducing oxygen levels may be impractical in airflow environments or in clean rooms that are occupied by people. Therefore, removing this leg of the fire triangle may not be a viable option.

### **Passive and Active Controls**

Control solutions for the fire risk involving process tools were developed by further analysis of each fundamental fire triangle element. A process to examine potential passive and active controls for each of these elements (fuel, ignition source, and oxygen) was used to meet the objective of reducing the loss exposure of fire to an acceptable level.

From the risk identification process, fuel sources were determined to include chemicals used in wafer fabrication processing, tool materials of construction, and peripheral materials within the facility systems supporting fabrication processing. Where flammable or combustible chemicals are used, tools are constructed with noncombustible materials to provide passive protection. Active controls of the chemical delivery systems incorporate fail-safe shut-off controls to prevent continued fuel or chemical dispensing.

Process tool construction materials were selected for compatibility for wafer processing within acid environments. Research was conducted in conjunction with the plastics and insurance industries to determine if acid resistive materials could be developed that would meet process compatible requirements and also meet non-fire-propagating material requirements.

The prevalent ignition sources identified from the risk identification process were from electrical component failure within the tool, including the heating elements and controls. Passive control solutions for electrical failure are limited. Active controls would remove the energy source upon incipient detection of fire. Other solutions included removing the heating elements from the tool itself by heating the liquid acids solutions remotely and circulating heated liquids to the tool.

### **Implementing Solutions**

For the fire event within the clean room, the acceptable level of loss was defined to be a fire within a process tool that remains contained to the tool and does not propagate to an adjacent tool or equipment. The resulting physical damage and factory business impact cost are compared to a predetermined acceptable level of loss amount.

Intel Risk Management led industry efforts in developing insurance industry and fire protection equipment vendors' partnerships to conduct fire research and testing of failure modes and fire growth within process tools. Fire detection and suppression system solutions were developed and tested to work within the corrosive environments within these tools. Validation, testing, and approval of local application fire suppression system add-ons required coordination with many Intel groups within technology development and manufacturing. An implementation plan was developed to install fire detection and suppression solutions on existing tool bases without affecting wafer processing production and yields. New process tool orders had to have pre-installed fire detection and suppression systems prior to delivery when needed.

Material science engineers from the plastics industry, tool equipment manufacturers, and the insurance industry partnered with semiconductor fabrication companies to test and develop potential non-fire-propagating materials. The criteria, also known as the 4910 Protocol defines a set of testing requirements that include a Fire Protection Index (FPI), Smoke Damage Index (SDI), and Corrosion Damage Index (CDI). The materials meeting the fire propagation and micro-contamination requirements were tested for process compatibility of the acceptable materials by technology development groups. Technology development process controls determined the successful materials were acceptable for use. Intel Risk Management drove the implementation phase beginning with the intercept of 300mm process equipment generations through partnerships with Intel stakeholders. Today SEMI S14 (Fire Risk Protection) has been developed and is the accepted standard to assess tool fire risk and controls. Intel's EHS group manages this one element of the overall effort to address occupant safety, health, and environmental risks addressed elsewhere in this issue of

the *Intel Technology Journal*. A limitation metric of 1 pound per square foot of tool footprint was integrated in tool purchasing specifications. The process technology transfer process for manufacturing proliferate the successful result of limited catastrophic fire exposure within the Intel FAB network.

As part of the review process, a program was implemented to eliminate several fire suppression systems originally required on new tools as part of the program, based on updated risk assessments. The program was extended to remove some of the legacy local fire suppression systems on the existing process equipment tool base to capture cost savings.

## NATURAL HAZARDS

### Building Design for Windstorms

Tropical windstorms create severe challenges to Intel buildings that are within geographic areas prone to this natural hazard. These regional events cause devastation in a widespread area, and Intel sites must rely on resources available to reduce catastrophic loss. A large property insurance carrier, FM Global, reports that over the past 25 years, wind-related damage accounted for over 11% of their property losses, and 70% of those losses were from severe tropical storms such as hurricanes and typhoons [1]. The loss history indicates that in most cases the main structure of the building does not sustain damage; however, damage occurs when the building components such as roofs, walls, and windows fail and the interior is subjected to the elements. Property damage losses can be vastly mitigated in severe storms if the integrity of building components and interior occupancy do not become compromised by low-frequency but high-severity wind and wind-driven rain.

### Windstorm Basics

The Risk Identification process for wind exposure begins with understanding what potential site-specific conditions may occur within the expected useable lifetime of the building. Historical wind maps are based on statistical analysis to determine the probability of maximum wind speeds to occur in a given year. The wind speeds are measured and averaged to determine various time durations of sustained winds and peak gusts. An average wind speed peak in a given year and the peak wind within a multi-year frequency period could be an event. These intensity factors establish the basis of building system design requirements for wind.

Wind and wind forces become dynamic as they meet obstructions in their paths. This often occurs around buildings in urban areas. As wind changes direction and moves around buildings, significant suction and uplift

forces are created, particularly on the corners and perimeters of a building, which stresses the building roof systems.

### Controls for Wind Exposure

Passive control measures would include avoidance of these exposures by simply not building in high-exposure wind areas. Although Risk Management is involved in the site selection activities of Intel and provides natural hazard exposure analysis as part of this activity, obviously other economic business factors drive the business decision to build in a given location. Intel has moved manufacturing operations from high hurricane wind exposure locations in its history: it sold its Puerto Rico Test and Board facility in the 1990s and its Barbados Assembly facility in the 1980s. Wind loss exposures are still present at the Cavite site in the Philippines and in Pudong and Shanghai, China Semiconductor Manufacturing facilities.

The options for active controls are rather limited for windstorms. However, the site Emergency Preparedness Programs that address site exposures and conditions are a critical component of loss control and mitigation during a severe windstorm. Plans need to be specific but realistic: the resources, such as manpower, need to be available in the case of an emergency. Installing storm shutters on windows, doors, and other exterior openings when windstorms are predicted is an example of a scenario-based plan element. Other controls embedded in emergency preparedness include Business Continuity planning for operations of the site and the supply chain before and after the event to reduce the business interruption consequence of windstorms.

### Implementing Solutions

Property loss control solutions for wind exposures to existing building and roof systems are specific to the building and the immediate general site area. Factors also include the age and life expectancy of the building, the number of people in the buildings, the ability to make improvements to the existing building components and structure, and the cost of making any improvements.

Risk Management defines the appropriate passive wind controls to be used for roofing and wall systems of buildings through the existing Master Design Specification (MDS) system process. The process to implement passive controls for new construction of buildings is embedded in Intel's established design review process through all phases of a project. Various stages of review allow for the appropriate timing to incorporate wind mitigation design features. Minimizing the number of windows in manufacturing buildings early in a project is an obvious example. More challenging is understanding

the building system design and capabilities to incorporate property loss control.

Mechanical fastening of the roof coverings and membranes to the structural elements along the roof perimeter and corners is the preferred method to mitigate wind uplift forces. As part of the overall property loss control audit process, existing sites are periodically evaluated, and feedback is coordinated with local project teams on potential roof upgrades or replacement. Risk Management is embedded in the review and approval process of these projects to ensure cost-effective property loss control of the building.

## **Flood**

Flood exposures can create challenges to Intel buildings that are prone to this natural hazard. Floods can cause devastation locally and in the surrounding areas. The property insurer, FM Global, reports its loss history indicates 20% of property flood losses are in buildings outside of designated flood maps [2]. Property damage losses can be vastly mitigated in severe storms if the integrity of building components and interior occupancy do not become compromised by wind and rain. Intel buildings will need to have their own resources available to mitigate catastrophic damage.

## **Flood Maps and Data**

The Risk Identification process for flood exposures begins with understanding what potential site-specific damage may occur. Historical flood maps are based on statistical analysis to determine the maximum water level over a specified interval of time and averaged for a given year. As with windstorm exposures, many geographic areas do not have good reliable data available for analysis. Risk Management conducts site-specific analysis to determine site requirements for finished floor elevations and also the locations of utilities and facility equipment that are vital to the continuance of manufacturing operations at the site.

## **Controls for Flood Exposures**

As with locations subject to windstorms, avoidance of sites subject to flooding is not always possible; i.e., passive controls. Active controls, although limited, are best implemented through site emergency preparedness programs that address the various exposures and conditions for a severe flood. Plans need to be specific in proactively addressing mitigation of the potential damage, as well as realistic in the availability of resources such as manpower in a regional emergency. Using sandbags, temporarily relocating equipment susceptible to water damage, and the use of pumping systems to displace water using reliable self-sufficient electrical power generators are examples of a scenario-based plan. Other controls

embedded in emergency preparedness plans include BC planning for operations at the site and the supply chain before and after the event.

## **Implementing Solutions**

Risk Management defines the appropriate finished floor elevations for new construction through the existing MDS system process. The process to implement passive controls for new construction of buildings is embedded in Intel's established design review process through all phases of a project similar to the windstorm exposure. Various stages of review allow for the appropriate timing to incorporate wind mitigation design features. Site-specific reviews are conducted to determine specific requirements.

## **MEASURING SUCCESS**

Intel's 300mm fabrication clean room environments have no loss history of fire losses. The measurement of loss expectancies within new process tools and semiconductor manufacturing facilities continues to validate loss expectancies that remain below predetermined acceptable levels.

Detailed studies for windstorm exposures were conducted in 2002 on Intel buildings in Cavite and Pudong. Deficiencies noted in the roof systems were evaluated for severity, potential impact to business operations in each building, and the cost and ability to remediate deficiencies. A prioritized remediation plan was developed in partnership with local site services to correct deficiencies. Typhoon Xangsane traveled near Cavite in the Philippines in September 2006 and in buildings where wind-resistive roof-fastening controls were in place, the roof systems performed well, and Intel did not incur significant property damage. These physical building system improvements as well as the well-developed emergency response plans for typhoons and flooding mitigated serious damage to manufacturing operations.

Risk transfer programs are a beneficiary of the successful results made in property loss control engineering. Reducing the catastrophic risk of loss through engineering control measures and Intel's excellent property loss history from hazard events allows Intel to take out insurance against hazards with optimal coverage and premiums.

## **CHALLENGES**

Codes are the minimum requirements established to safeguard the lives of building occupants: they generally do not address property conservation. If companies, such as Intel, want to design above the minimum criteria to help mitigate property losses, they have to consider

whether the costs are worth the additional investment. Companies need to understand the total cost delta of implementing improvements above minimum code relative to the level of loss they are prepared to accept.

The programs in place for managing the fire risk in clean rooms require continuous monitoring. Process technology development and the evolution of chemical processes used in manufacturing create challenges for our current acceptable materials of construction. Issues such as Electro Static Discharge (ESD) and off-gassing of materials expose wafer processing and can limit available materials for manufacturing as the transistor geometries continue to shrink. Implementing non-fire propagating material requirements within other manufacturing technology risk issues requires continued diligence. Potential processes for fabricating 450mm wafers will require all tools and construction materials to change. Embedding construction material management controls within existing processes will maintain passive control solutions of this fire hazard risk.

Determining and agreeing on the applicable wind speed design criteria relative to the design of building structures with design teams is not always a simple task. As previously mentioned, detailed wind speed data may not be available in various geographies. In these cases, engineering judgment based on available data collected at the site is required to determine the specific performance levels to meet the objective of adequate passive protection.

## CONCLUSION

As the Intel approach to doing business continues to change, the effect of risk of loss from hazard events changes as well. The Risk Management Process for identifying and quantifying hazard events is ongoing and remains an integral part of influencing the appropriate loss control measures to reduce the consequences of loss. The effectiveness of these programs can be measured in the efficient and cost-effective program management embedded in existing processes for defining and implementing risk mitigation controls within Intel's manufacturing environment.

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