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UNDERSTANDING THE SUPPLY CHAIN ENVIRONMENT AND BEST PRACTICES FOR MANAGING RISKS IN TODAY'S COMPLEX ECONOMY

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ABSTRACT

The objective of this paper is two-fold. Firstly, to inform the audience on the inherent risk of shortage of raw materials used to produce high-tech devices, sources and the different levels of stakeholders involved in the transformation process – all of which is a subset of the supply chain. Secondly, given that we live in a complex global economy within which changes are occurring rapidly, we need to develop an awareness of risks in our surrounding business environment and develop the skillset necessary to manage risks well.

1. INTRODUCTION

Because many high-tech electronic products permeate our everyday lives and are vital to our national defense, we should be concerned with the inherent risk of shortage posed by raw materials accessibility.

Section 2 describes the different raw materials used to manufacture devices like iPhones, their growth in demand and source of origins.

Different stakeholders (or companies) in the supply chain are interdependent on each other, which intensifies the risk of disruptions. 75% of manager say the supply chain risks today are higher than in 2005 [Ref 1, Ref 3]. However many companies do not have the right framework in place to mitigate risks due to supply chain disruptions. To handle risks well in a complex global economy, as leaders we need to know what questions to ask, be aware of the surrounding environment and challenges to the program, sources of risks and know how to manage risks well. For example, we need to make sure key risk indicators are identified do address program objectives. The actual decision makers, and not just data analysts, are the ones to be reviewing the risk metrics.

Section 3 explains why today's supply chain environment is complex and presents the best practices needed for good risk management and lessons learned from handling (or not adequately handling) risks.

Section 4 elaborates on the urgency for managing risks well by presenting key findings from the Fiscal Year 2017 Report to Congress "Annual Industrial Capabilities" published in March 2018 which addresses the status of manufacturing capacity and the defense industrial base of the United States of America [Ref 24]. The findings from the report draws a correlation between the accessibility of quality components and the importance of executing the risk management process and especially in addressing sustainment and obsolescence risks.

2. SUPPLY CHAIN

Today's global economy is more interconnected than it has been in the past. For example, to assemble a passenger vehicle, an automotive Original Equipment Manufacturer (OEM) procures materials from different corners of the globe. Within the automotive development cycle, these materials transfer ownership beginning from the raw material manufacturer, to multiple tiered suppliers, to the OEM and finally to the end-user.

The transfer of raw materials, the multiple-tiered suppliers, the OEM, end-user, technologies and processes used is the cornerstone of today's supply chain environment.

The Chevy Bolt and the iPhone 6S are universal symbols of the interconnectedness of the 21st global economy. Figure 1 and Figure 2 convey at a high-level, components that collectively make up these products for General Motors (GM) and Apple, respectively, and their global suppliers.

2.1 Metals and Rare Metals

A variety of metals and rare metals are used to mass produce high tech electronic devices [Ref 4]. They are used in developing advanced weapon systems needed for national defense, and energy saving and environmentally friendly emerging technologies such as: light bulbs, powerful fuel cell and batteries, solar panels, wind turbines, nuclear power plants, power air conditioners and electric vehicles. Rare metals are also used to create the brilliant colors on our smartphone screens [Refs 5 - 6].

The use of gold, copper and rare metals have increased 27 times in the past 100 years [Ref 6]. In addition, the world's growth of steel production has grown over the last 100 years. The growth has concentrated around 2 key periods (Figure 3) , the first period spanning 35 years after World War II and the second period due to the China-led economic growth starting in 2000 [Ref 7]. Table 1 lists the top 10 countries identified for global steel demand in 2018 [Ref 8].

Figure 4 and Table 2 show the rare metals used to build mobile devices and their source of origin respectively.

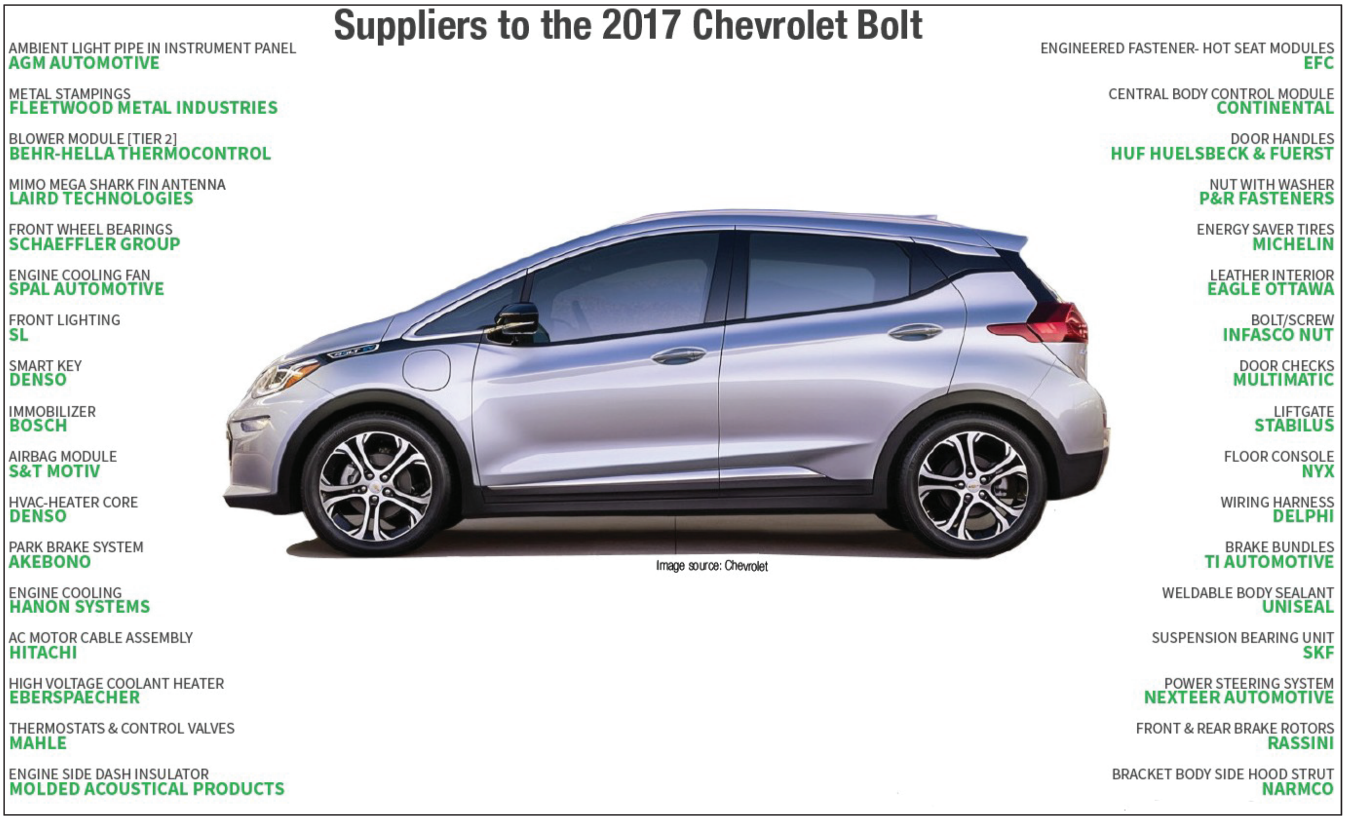

Figure 1 – Suppliers to the 2017 GM Chevy Bolt [Ref 9]

August 2017, Automotive News https://www.autonews.com/article/20170801/CUTAWAY/170729771/suppliers-to-the-2017-chevrolet-bolt

Display/Touch	Samsung (Suwon, South Korea)
Secondary Camera Module PCB	Omivision (Santa Clara, California, USA) AAC Technologies (Shen*zhen, China*)
Home Button / Fingerprint Sensor	Taiwan Semiconductor Manufacturing Company (HsinChu, Taiwan)
Ambient Light Sensor / Microphone PCB	AAC Technologies, (Shenzen, China)
Loudspeaker, receiver	
Center Panel (Chassis)	
Volume up/down ring silent PCB	
SIM Card Tray	
Primary Camera Module	Sony (Tokyo, Japan)
Battery	Sunwoda Electronics (Shenzhen, China) Simplo Technology (Hsinchu, Taiwan) Desay Battery Tech (Shenzhen, China)
Main Printed Circuit Board	Compeq Manufacturing (Taoyuan, Taiwan) Unitech Printed Circuit Board (New Taipei City, Taiwan) Unimicron Technology (Taoyuan, Taiwan)
Engine Assembly	AAC Technologies (Shenzhen, China)
Camera Flash / Power Button PCB	
Loudspeaker Assembly	Cirrus Logic (Austin, Texas, USA)
Main IO / Audio Jack PCB	
Enclosure, Main	Catcher Technology (Tainan, Taiwan)
RIP headphone jack	

Main printed circuit board (display side) Key components:	
LED backlight Retina display	Texas Instruments (Dallas, Texas, USA)
A9 APL0898 application processor	Samsung (Suwon, South Korea)
DRAM	Micron (Boise, Idaho, USA)
SIM Card Slot	
Accelerometer and gyroscope MPU-6700	InvenSense (San Jose, California, USA)
Baseband Processor MDM9635M	Qualcomm (San Diego, California, USA)
Power Amplifier AFEM-8030 3G/4D mid band PAD module	Avago (San Jose, California, USA)
Accelerometer BMA280	Bosch Sensortec (Gerlingen, Germany)
Envelop tracker QFE1100	Qualcomm (San Diego, California, USA)
Power Amplifier Sky77812-19 Low bad 3G/4G PAD module	Skyworks (Woburn, Massachusetts, USA)
Power Amplifier TQF6405 PAD module	Qorvo (Greensboro, North Carolina, USA)

Main printed circuit board (battery side) Key components:	
Battery Charger SN2400ABO	Texas Instruments (Dallas, Texas, USA)
Class D Audio Amplifier 338S1285	Cirrus Logic (Austin, Texas, USA)
Power Management	Texas Instruments (Dallas, Texas, USA)
Flash Memory H23QDG8UD1ACS	SK Hynix (Icheon, South Korea)
Barometer BMP280	Bosch Sensortec, Gerlingen, Germany
Power Management 338S00120-A1	Dialog (Reading, Britain)
Audio codec (338S00105)	Cirrus Logic (Austin, Texas, USA)
Near field Communications controller 66V10	NXP (Eindhoven, Netherlands)
WiFi module 339S00043	Universal Scientific Industrial (Shanghai, China)

Figure 2 – Components Inside Apple iPhone 6S And Their Suppliers [Ref 10]

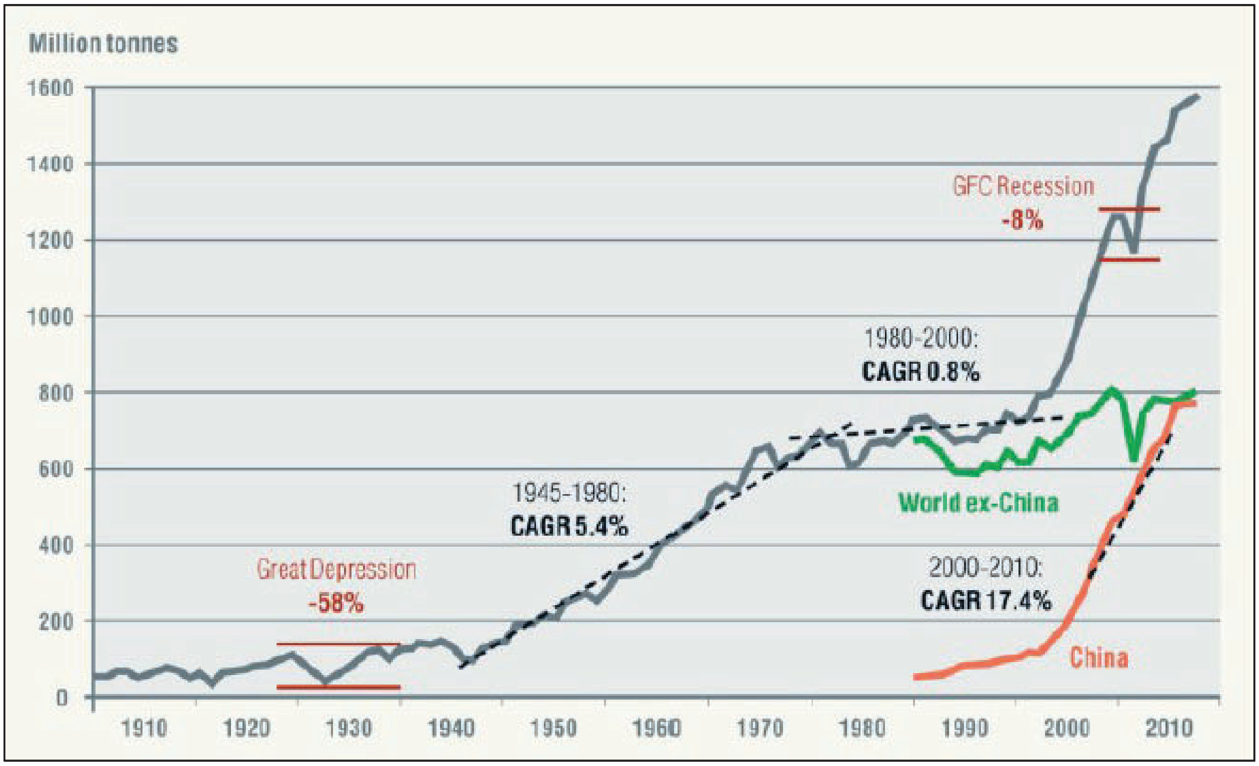

Figure 3 - Worldwide Steel Production, Compound Annual Growth Rate (CAGR) 1910 – 2015 (sources: IISA/WSA and Metalytics Analysis) [Ref 7]

TABLE 1 - 2018 Projected World World Steel Demand (based on 2017 anlysis) [Ref 8]

Top 10 Countries in 2018

TOP 10 (2018)	
Country	ASU [Mt]
China	765.7
United States	97.3
India	92.1
Japan	64.5
South Korea	56.4
Germany	41.6
Russia	40.5
Turkey	35.5
Mexico	27.6
Vietnam	27.0

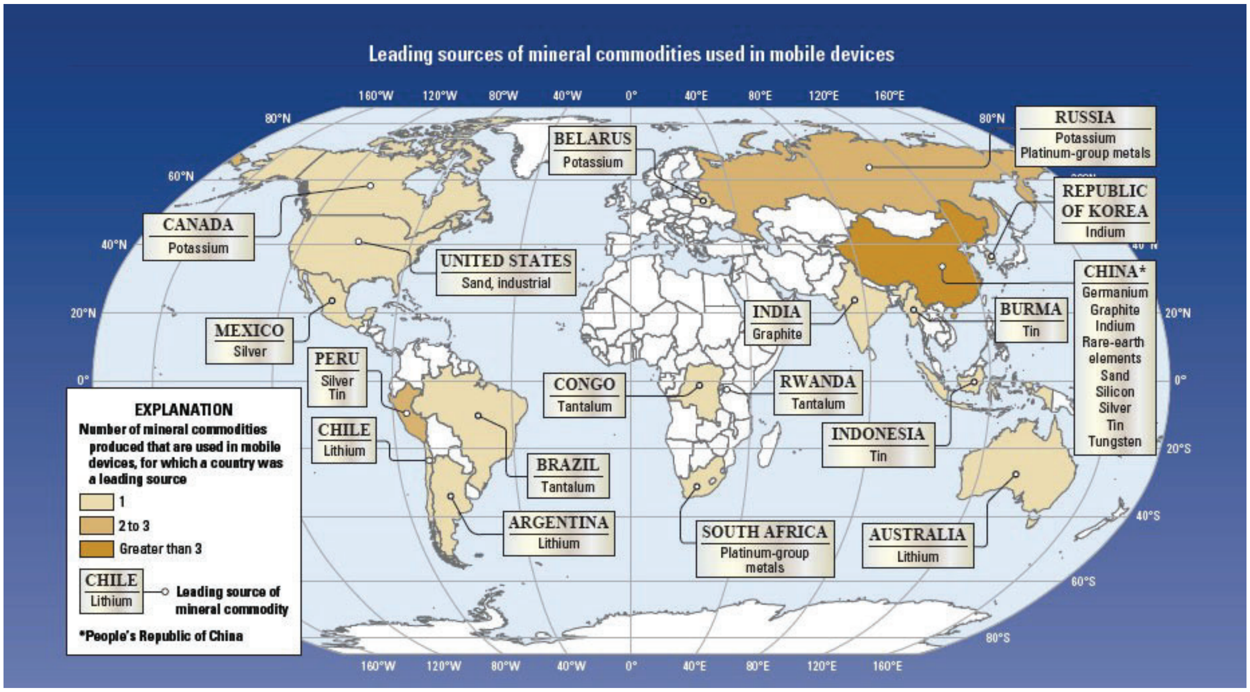

Figure 4 Leading Sources of Rare Minerals used in Mobile Devices [Ref 11]

TABLE 2 – Examples of Mineral Commodities Used in Mobile Devices [Ref 11]

Examples of mineral commodities used in mobile devices

Mineral commodity	Leading global sources by decreasing tonnage in 2014	Mineral source(s)	Applicable properties of the commodity	Where the commodities are used in a mobile device
Germanium	China[1]	Sphalerite	Conducts electricity	Battery, display, electronics and circuitry, and vibration components.
Graphite	China, India	Graphite	Resists heat, conducts electricity and heat, resists corrosion, and has a high performance-to-weight ratio	Battery anodes.
Indium	China, Republic of Korea	Sphalerite	Transparent and conducts electricity	Liquid crystal displays.
Lithium	Australia, Chile, Argentina, China	Amblygonite, petalite, lepidolite, and spodumene	Chemically reactive and has a high performance-to-weight ratio	Battery cathodes.
Platinum-group metals	South Africa, Russia, Canada	More than 100 different minerals	Conducts electricity	Circuitry, capacitors, and plating.
Potassium	Canada, Russia, Belarus	Langbeinite, sylvite, and sylvinite	Strengthens glass	Screen glass.
Rare-earth elements	China	Bastnäsite, ion adsorption clays, loparite, monazite, and xenotime	Highly magnetic; blue, green, red, and yellow phosphors; and optical-quality glass	LED phosphors, screens, speakers, and vibration motors.
Sand, industrial	China,[2] United States	Silica sand	Gives glass clarity	Screen glass and semiconductors.
Silicon	China	Quartz	Conducts electricity	Semiconductors.
Silver	Mexico, China, Peru	Argentite and tetrahedrite	Conducts electricity	Circuitry.
Tantalum	Rwanda, Brazil, Congo (Kinshasa)	Columbite and tantalite	Stores electrical charge well	Capacitors.
Tin	China, Indonesia, Burma, Peru	Cassiterite	Transparent and conducts electricity	Liquid crystal displays and circuit board solder.
Tungsten	China	Scheelite and wolframite	Highly dense and durable for vibrator's weight component	Vibrator.

[1]People's Republic of China, hereinafter referred to as China.

[2]China is the world's largest producer of industrial sand; however, available information is inadequate to formulate a reliable estimate of output levels.

3. Risk Management

3.1 Drivers Leading to Increased Uncertainties

The 21st century economy is filled with many uncertainties. The five drivers leading to an increasing trend in uncertainties are [Ref 16]:

1. **Faster pace of change**: Our ability to predict the future is limited due to the technological advancement of information and communications systems and shorter product life cycles.
2. **Increasing complexity**: Our ability to identify different risks ahead of time is limited due to the increasing complexity of organizational processes and systems.
3. **Multi-polar global order**: Our ability to foresee global events is limited due to the emergence of new economic powers like Brazil, Russia, India and China (BRIC nations) and not understanding what roles these nations play in the global stage.
4. **Globalization**: Our ability to safeguard our organizations from major disruptions is limited because we live in an ever increasing interconnected global economy. In such an economy, a local risk originating in another part of the world can quickly become a global risk affecting everyone in the supply chain.
5. **Interconnected risks**: There is an increasing number of risks that are interdependent on each other. One type of risk may evolve into another risk.

As a result of increasing uncertainties, organizations need to develop better risk management capabilities. Leaders should embed these capabilities into their organization's day to day business operations, processes and procedures and organizational culture.

3.2 Why Are Organizations Not Effective In Managing Risks?

Organizations may have established a risk management process and implemented a tool to help manage risks. However, in spite of this many organizations are still not effective in managing risks. The main reason for the difficulty of managing risks is leadership does not place a priority on risk management. The other reasons precluding organizations from developing the capability to manage risks well are:

- People are reluctant to step out of their defined functional roles and work collectively with other departments [Ref 12].
- Not communicating the rationale and expectations for risk management [Ref 34].
- Risk indicators not aligned with program objectives. Actual decision makers not reviewing data collected describing indicator trend.
- Programs have defined the rating criteria for deviations in cost, performance and schedule and also the likelihood of occurrence, however programs seldom refer to the definitions while rating risks. Many times, risk owners rate the risk based on their intuition [Ref 15].
- Risk owner does not document rationale explaining why they rated a risk a certain value. The downside of the absence of documentation is when a new personnel takes ownership of the risk, they will not have the necessary background to understand the rating [Ref 15].
- Team members confuse risk with an issue. A risk is an event that has a probability (where $1\% \leq \text{Probability} < 100\%$) of occurring in the future and its

consequence and impact has not yet been felt. An issue is an event that has already (Probability = 100%) occurred and its consequence & impact are being felt at the present time.

- Program manager or key decision maker not chairing a Risk Review Board meeting to review risk handling plans & progress and risk status regularly. Programs that are in a fire-fighting mode or resource constrained place risks on the back burner.

3.3 Incorporating Risk Management

The basic steps needed to incorporate risk management process within an organization are described at a high level in the following paragraphs:

1. **Process Planning**: Develop a risk management plan describing how to execute the risk management process, the different steps of risk management, stakeholders involved and their roles and responsibilities. Understand program scope, schedule and cost requirements.
2. **Identification**: Identify risks impacting program cost, performance and schedule.
3. **Analysis**: Determine root cause, assess risk likelihood and consequence and understand its impact. Prioritize risks.
4. **Handling**: Define and execute risk handling plans to mitigate risks.
5. **Monitoring**: Monitor progress of risk handling plan.

Figure 5 describes the five steps of the risk management process.

Figure 5 Risk Management Process [Ref 20]

3.4 Identify Risks

Risk Management takes place in all phases of the program lifecycle. The form and urgency of the risk changes as the program progresses through its lifecycle. All through the program lifecycle, we need to be asking ourselves questions on possible risks impacting the program. Examples of questions we should be asking ourselves and others to help identify risks are [Ref 12]:

- What are the critical factors/variables in the product life cycle and when do these factors become significant?
- What is the threshold or tolerance before the risk is realized?
- What are the variables deemed important by end-user?
- What are the critical components used in the production process and their source of origin / supplier?
- When will parts become obsolete? Have alternatives been identified to replace obsolete parts? Are suppliers of the new parts certified?

There are different kinds of risks affecting a program. Risks arise due to schedule constraints, product complexities, the surrounding organizational culture or supply chain complexities.

Sources of Schedule Risks

Examples of sources of schedule risks are [Refs 32 - 33]:

- Project schedule not decomposed to lower level of details describing work to be performed, end deliverables, owner and delivery dates.
- Not aligning the project schedule with scope and available resources.
- Preparing aggressive schedules in the early phase of the project in order to win the contract.
- Favoring a fast-track implementation and late starts which compresses the schedule.

Sources of Product Development Risks

Examples of sources of product development risks are [Ref 13]:

- System has too many features which contributes to product complexity.
- System not having an open architecture which forces customer to procure a customized system instead of a COTS item which leads to additional costs.
- System not having a wide enough margin of error to prevent performance and operational failures.
- Customer requirements and system requirements not properly defined and understood.

Sources of Organizational or Cultural Related Risks

- Low-balling the cost of developing or upgrading the system.
- Key project members leaving the program at a critical phase of the lifecycle.
- Customer keeps changing requirements over the objections of the program manager.

Sources of Supply Chain Risks

Examples of sources of supply chain risks are:

- Depending on a sole-source supplier who may go out of business or one that decides to increase the price significantly.
- Stockpiling components that can become obsolete with new technology.
- Materials that are vulnerable to sudden changes in demands and price fluctuations.

As program managers, we need to understand our environment and identify risks. Unless we handle risks adequately, we will keep on repeating the same programmatic mistakes.

3.5 Identify Key Risk Indicators

While we monitor program status, we can also measure and track risk indicators to determine changes in risk exposure. In order to track risks, we have to clearly understand the existing risks and develop the necessary metrics to identify and track risk indicators. When we fail to do this, programs fail to assess risk exposure and identify trigger points.

Approaches to help with identifying key risk indicators are [Ref 14]:

- Focus on scenarios most controllable by the program and on risks that have the greatest likelihood of occurring.
- Weight each key risk indicator and focus on those with the highest weighting.

- Collaborate with subject matter experts, functional leads, and different organizations like Engineering, Procurement, Financing and R&D to define risk indicators common to all.

3.6 Risk Handling Plans

How we define risk handling plans to mitigate risks depends on the source of risk [Ref 21].

Risks due to demand uncertainty can be handled by reducing the cycle time, speeding up the production process and when possible relocating the production facility close to the customer base.

Risks due to product failures can be best handled by rewriting the contract so that maintenance and servicing are part of the contractual agreement. An example of this is when Rolls Royce, a major manufacturer for aircraft engines, dealt with fixing many grounded planes that had engine failures. Due to the high cost in repair time, labor and materials, risk of engine failures was a major concern for Rolls Royce and its customers. So in the 1970s, Rolls Royce rewrote its contract charging customers for repair services in terms of the engine's flight hours. Charging customers in terms of engine's flight hours incentivized Rolls Royce to improve its product and maintenance process. Other similar examples of where servicing and maintenance are part of the contractual agreements to achieve labor and materials cost savings are:

1. **Rail Transportation Industry**: The German rail vehicle manufacturer Bombardier charges its customers for maintenance in terms of miles driven.
2. **Construction Industry**: As a major manufacturer for construction equipment, Caterpillar charges construction companies according to the amount of earth moved.
3. **Automotive Industry**: Major automaker OEMs, reduce risk of vehicle breakdowns by offering factory and extended warranties to their customers. Availability of extended warranties depend on vehicle's age and miles driven.

3.7 Risk Management Capabilities & Competitive Advantage

<u>Risk Management Capabilities</u>

Risk management capabilities to develop are [Ref 16]:

1. Recognize potential risks.
2. Determine risk severity by assessing the likelihood, consequence and impact of each risk.
3. Know how to prioritize risks.
4. Define common key risk indicators unique to the program and common across organizations.
5. Monitor key risk indicators using well-established sensing/monitoring processes and, understanding the significance of the data collected, ensure key decision makers are reviewing the data to understand changes to risk exposures.
6. Collaborate with different teams and suppliers to define and execute risk handling plans.
7. Adapt an organizational culture that is flexible in handling risks.
8. Identify additional risks and opportunities arising as a byproduct of handling original risk.
9. Review risk status regularly with key decision makers and stakeholders.
10. Apply lessons learned from past and current risks to other programs.

Competitive Advantage

Managing risks well allows for an organization to differentiate from its competitors [Ref 17] and [Ref 18]. An organization can leverage risk management capabilities to gain a cost advantage and product/system differentiation. Four major ways an organization can turn risk management capabilities into a competitive advantage are [Ref 16]:

1. **Continue providing support** when others cannot: Develop the ability to deal with disruptions and continue supporting customers. When we continue providing support in spite of these disruptions, we develop the perception of being resilient and capable of dealing with unforeseen events.
2. **Seek riskier business**: The ability to deal with risks better than competitors allow organizations to venture into riskier business that bring with it a higher potential earning.
3. **Excelling in day-to-day performance**: Having the ability to deal with non-disruptive unrewarded risks during stable periods allows companies to develop qualities of: (a) Being flexible with unexpected events, (b) Being responsive and agile with changing environments, (c) Building strong collaborative and partnering relationship with others, (d) Making proactive and informed decisions instead of reacting haphazardly and (e) Communicating well with stakeholders.
4. **Building a resilient image**: By having strong risk management capabilities, organizations are perceived by their external counterparts as being resilient in the face of heightened uncertainties.

Figure 6 describes how a strong leadership focus and commitment to risk management enables an organization to achieve competitive advantage [Ref 16].

Figure 7 on the other hand, describes the discrepancies between automotive supply chain executive officers (CEOs) and automotive OEMs chief financial officers (CFOs) in whether risk management helps in strengthening their financial performance [Ref 19].

3.8 Real-life Business Cases and Lessons Learned

Business Case 1: Demand and supply of Palladium

Rare metals like palladium are used in automotive exhaust systems to make emissions cleaner. All the large automotive OEMs buy rare metals used in the design and manufacture of vehicles that satisfy emission requirements. Platinum, palladium and rhodium are dissolved in liquids and spread thinly over ceramic honeycombs inside the catalytic converter and dried. These metals had the unique ability of stimulating chemical reactions inside the hot exhaust and converting pollutants into harmless compounds.

In January 2002, Ford did a $1 billion write-off in the stockpile of the rare metal palladium [Ref 31]. Russia is the world's largest supplier of the rare metal palladium [Ref 22]. In late 1990s, Russia decided to freeze shipment of palladium which caused the price of palladium to jump by 70% to $350 per ounce. By 2000, palladium was priced at $700 per ounce. As a result, Ford stockpiled palladium and lined up long-term supply contracts. The hoarding of an

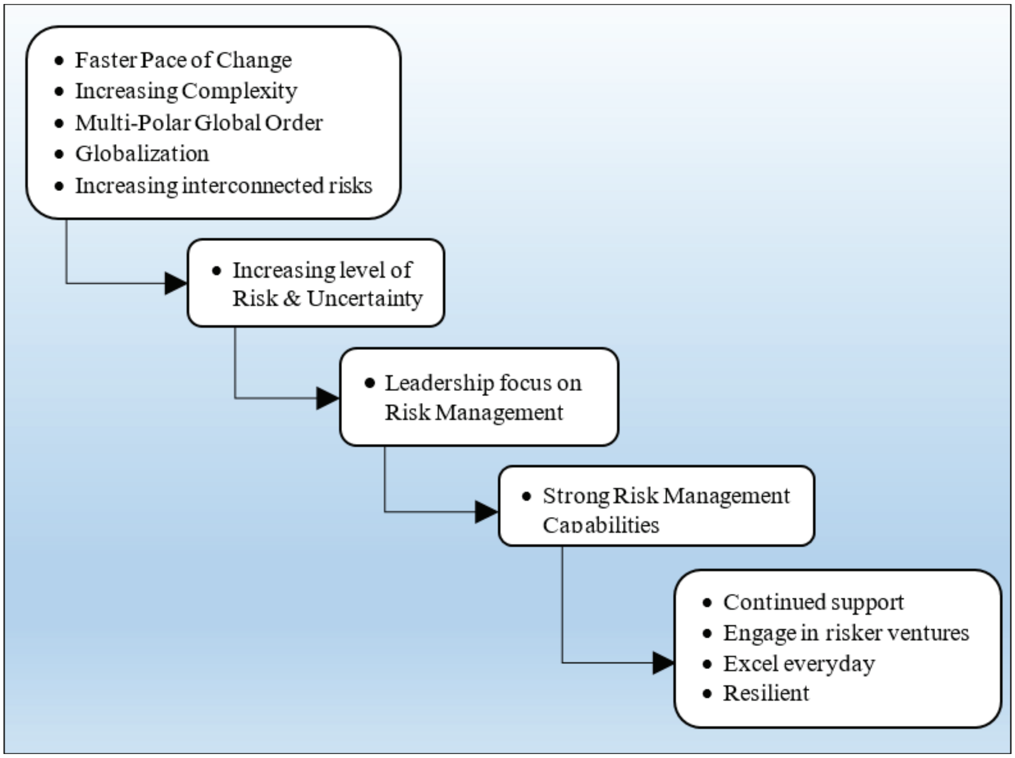

Figure 6 - Risk Management as a Source of Competitive Advantage [Ref 16]

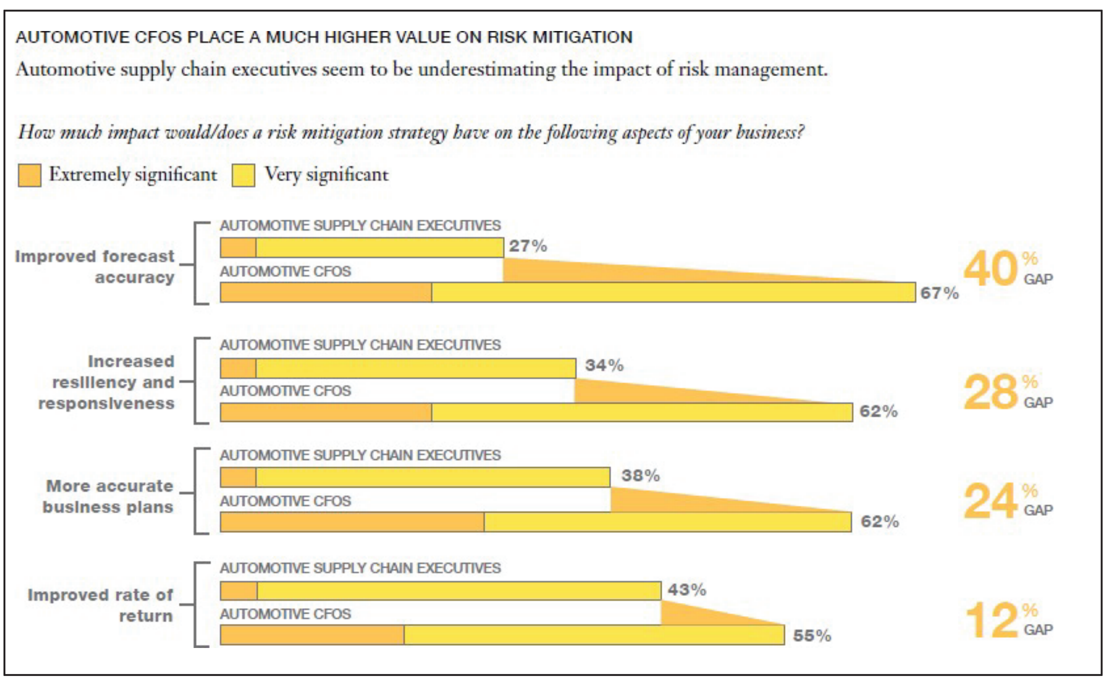

Figure 7 - Automotive CFOs Place a Much Higher Value on Risk Management Capabilities [Ref 19]

unusually large quantity of palladium was in anticipation of growing needs and risk of price volatility and unpredictable supplies from Russia. This write-off could have been avoided, if the procurement department had consulted with R&D on what their technology development plan was and with the financing department to leverage existing financial strategies to bet against the risk of purchasing a volatile commodity like Palladium.

Due to the price volatility and unpredictable supply of palladium, the R&D arm of Ford had already found solutions to lessen Ford's dependency on using palladium in future exhaust systems.

<u>Lesson Learned</u>: Work across different organization like Product Development, Procurement, Financing and Research & Development to define common cross-organizational risk indicators.

<u>Business Case 2: How Nokia and Ericsson Responded to a Fire at its Supplier's Facility [Ref 16, Ref 23]</u>

Nokia and Ericsson are two major cellphone manufacturers and Royal Philips is their common supplier. In March 2000, a fire had broken out in a Philips owned fabrication facility located in New Mexico. The fire was extinguished in under ten minutes. However because the fabrication of semiconductor chips takes place in a clean-room environment, where no more than one speck of dust can exist per cubic foot, the fire induced smoke and triggering of water sprinklers had contaminated millions of chips that were ready for shipment. The contamination of millions of chips meant that these fabricated chips could not be integrated into cellphones as it would compromise cellphone functionality.

Before the fire, Nokia had spent over 5 years developing and integrating into their organizational activities an enhanced monitoring process to monitor the status of chip inflows necessary for cellphone production. Nokia had learned about the fire in the Philips plant during a routine check of chip status. Three days from the incident, Nokia had set up a task force to closely monitor Philips' recovery. The Nokia task force also implemented a number of actions to handle the risk to their cell phone production. Some of these mitigation actions included working with different Philips factories in Eindhoven and Shanghai to rearrange their production plans, modifying some chips per consultation with Philips so chips could be produced in Philips and non-Philips plants, and finding two alternative suppliers to produce the affected chips. As a result of Nokia's leadership, initial sensing and learning about the problem and its rapid mitigation actions, the production and delivery of Nokia cellphones were not adversely impacted. On the other hand, Nokia had expanded its global market to 30% and its profits rose by 42% in Q3 of 2000.

Ericsson did not step up its activities to handle the risk until early April, which was one month too late. As a result of not effectively responding to the disruption of chips delivered to its factories, Ericsson reported an operating loss of $200 million in its mobile phone division in Q2 of 2000 and a 3% loss in market share. Due to a chain of financial losses, Ericsson was eventually acquired by Sony in October 2001.

<u>Lesson Learned</u>: Develop an effective sensing/monitoring process, actively analyzing the information and correlating the information received to program goals and

determining whether there is a negative impact. Adapt effective actions to minimize the outcome of the negative impact. Work across organizational boundaries and jointly with partnering suppliers.

4 US Defense Industrial Base

In Fiscal Year 2017, President Trump issued Executive Order (EO) 13806, "Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States" [Ref 24]. Some of the key elements EO 13806 touched on are:

- Identifying essential raw materials needed
- Identifying and assessing supply chain risks and disruptions
- Measuring resilience of the U.S. manufacturing and defense industrial base

Figure 8 summarizes the objectives of EO 13806. Like other industries, the defense industrial base is affected by factors like obsolescence, foreign dependency, fluctuating demand, industry consolidation, loss of design and manufacturing skills for critical products, globalization and changes in technology and manufacturing.

For many defense contractors (especially with prime system integrators), one major risk lies with lower tier suppliers, where their risks in turn can be due to [Refs 25 – 29]:

- Not delivering products on time.
- Not adhering to industry-wide standards for engineering and quality assurance.
- Not meeting customer requirements.
- Exposure to fluctuation of prices for raw materials that are sourced globally.
- Cost overruns due to unforeseen difficulties in new technologies.
- Technology obsolescence & sustainment.
- Technical difficulties during development of new technologies due to complex requirements.
- Difficulty combining operations and processes of newly merged companies.
- Financial and operational difficulties of lower-tier suppliers.
- Procurement of counterfeit and non-certified parts.
- Warranty and servicing concerns.
- Material supply constraints.
- Future direction of domestic and global economies (like Brexit) and its impact on global demand.

4.7 Electronic Components within Department of Defense (DOD)

Electronic components allow for defense systems to perform capabilities like communicating and transmitting voice and video, sensor and system health data, sensing changes in the system state and surrounding environment, controlling system operation, movement and weapon fire. Companies like Lockheed Martin, BAE Systems and Ground Dynamics Land Systems are prime system integrators which assemble and produce defense systems. They obtain components from lower tier suppliers who in turn globally source materials and parts. The tiering of providers can be described as follows:

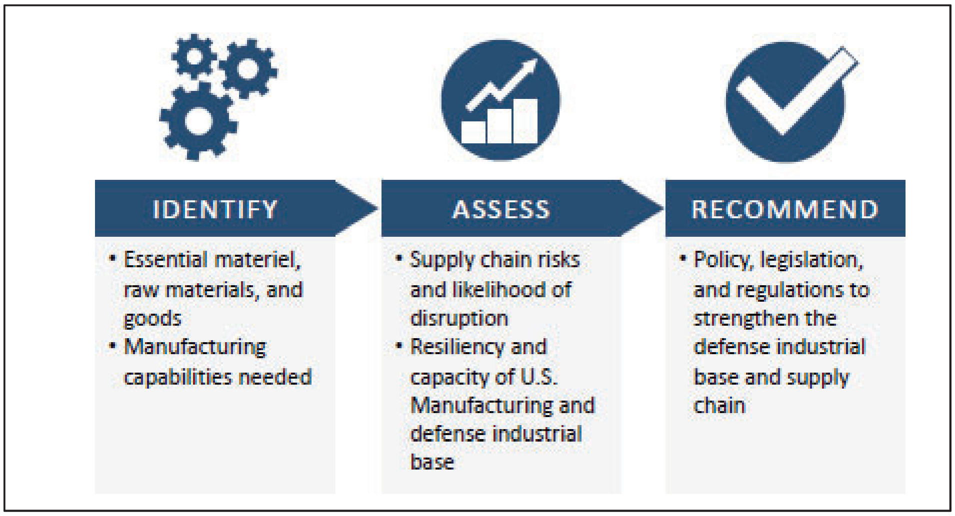

Figure 8 Industrial Base Assessment Approach for EO 13806 [Ref 24]

- 1st tier –Prime Systems Integrators (example is GDLS producing the Stryker vehicle)
- 2nd tier –Suppliers that assemble electronic components (examples are communication systems, engine control modules, sighting sensor systems)
- 3rd tier - Suppliers that manufacture individual component like integrated circuits (examples are microelectronic components like transducers, amplifiers, digital signal processing cards, substrate wafers)
- 4th tier - Suppliers at this level are providers of design tools and are mostly not aware of the final end use in defense products (examples include providers of electronic circuits design software like Mentorgraphics and PSPICE).

Problems arising at the 2nd or 3rd tiers can impact the system performance both at the prime systems integrator or USG. The difficulty lies in pinpointing at what level the root cause lies and who has ownership for resolution.

Semiconductor Industry

The semiconductor industry is responsible for producing today's electronic components. The U.S. Semiconductor Industry spends 30% of its sales on R&D more than any other industry with the exception of biotechnology and pharmaceutical industries. After aircrafts and industrial suppliers, semiconductors manufactured in the U.S made up the third largest capital export in 2015 amounting to greater than US$40 Billion.

Printed Circuit Boards (PCBs): PCBs provide the substrate wafers and interconnects for various integrated circuits and components that make up an electronic system. China owns 50% of the PCB global market share. Companies like Foxconn hold 1/3 of the world market share of which Apple Inc is one of its biggest customers.

Semiconductor Manufacturing Equipment Suppliers (SMES): Figure 9 shows semiconductor manufacturing equipment suppliers for different process nodes. Process nodes are the minimum dimensions for transistors used within microelectronic circuits which are built on a single chip. Smaller dimensions allow for more transistors to be placed on a single chip which leads to increased functionality and processing speed and performance. To assist a reader who is not familiar with semiconductor concepts, Figure 10 and Figure 11 respectively describe how decreasing transistor dimensions allow for more transistors to be packed together which allows for faster processing.

4.2 Ensuring Integrity of Electronic Components [Ref 30]

The DoD microelectronic supply chain is vulnerable to risk of performance failures & device tampering due to the difficulty in managing lower tier global suppliers, increasing device complexity, and low production volumes of defense products [Ref 30].

According to Army Aviation and Missile Research (AMRDEC), 70% of electronics become obsolete before they are fielded. It normally takes 8 years on average to develop a new defense system from concept phase. This is 4 times longer than the normal development cycle within the electronics market, which is around 2 years [Ref 24].

Risk severity (whether it is a high, moderate or low risk) to electronic components need to be analyzed as a function of:

- Consequence: How serious is the Impact on the System/Mission? What is the criticality of failure – what functions are impacted?
- Likelihood: Define likelihood in terms of:
  - Vulnerability - How susceptible is a component to tampering / compromise leading to negative impact on consequence?
  - Threat – Why would an adversary be motivated to tamper with the system and what is the ease of access to the system?
  - Obsolescence Threat – How soon will components be obsolete and how easy is it for suppliers outside of the trusted system network to provide defective aftermarket replacements?

Figure 12 describes graphically how to analyze the risk and also how execution of countermeasures assist in reducing the risk severity.

A number of DOD polices have been introduced to address non-performance of electronic components and their sustainability. To understand these policies better, the reader is advised to look at Ref 30.

5 Conclusion

This paper had briefly covered the raw materials needed to manufacture high-tech devices like cellphones. The limited global supply of raw materials and ever increasing global demands pose a risk of shortage that we will have to consider. This paper also went over the drivers explaining why it is difficult to predict future risks in a world with increasing uncertainties. In addition, it explains why many organizations have a hard time leveraging risk management capabilities and turning them into competitive advantage. Finally, it also shares the findings from EO 13806 which highlights how the need for having a robust and reliable supply chain (and especially for electronic components) is necessary for operation and sustainment of defense systems.

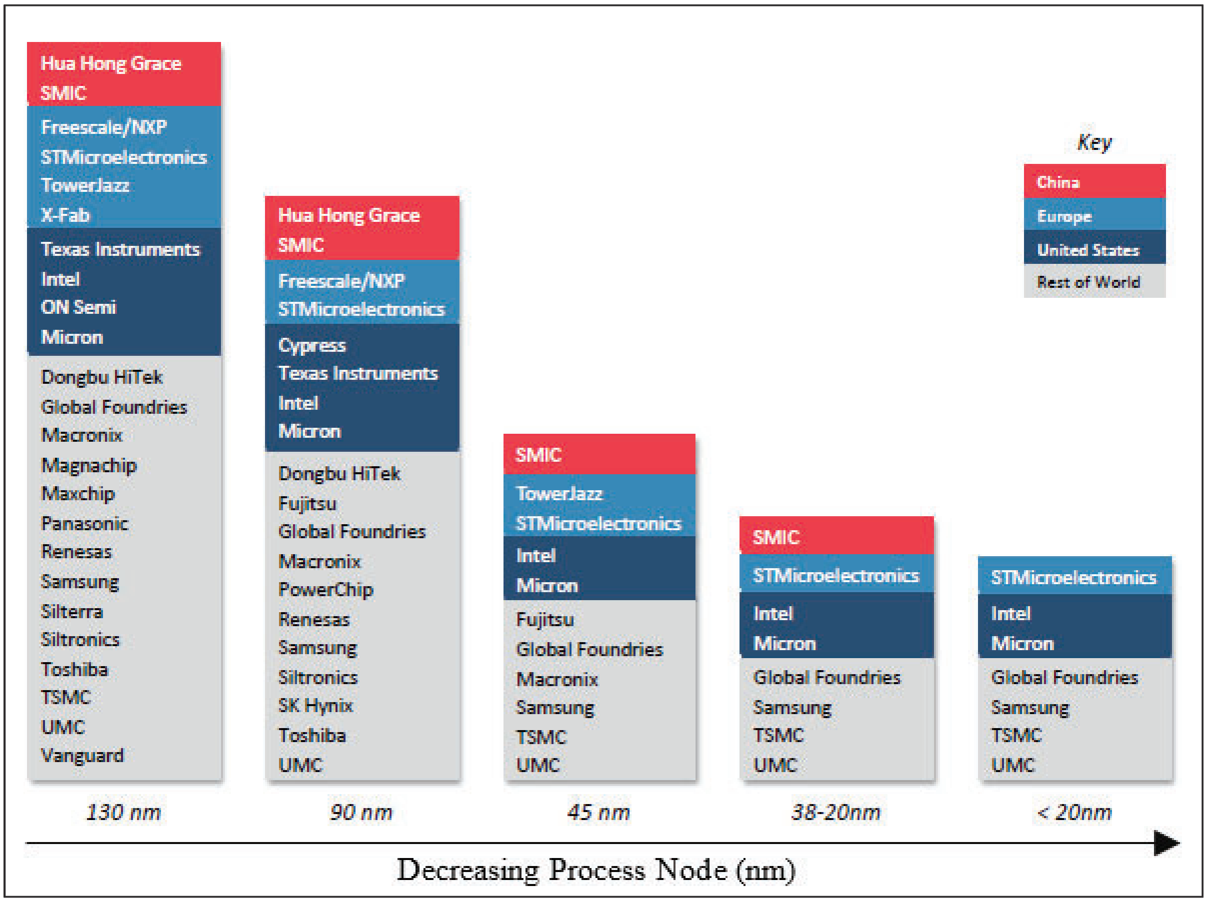

Figure 9 Semiconductor Fabricators By Process Nodes [Ref 24]

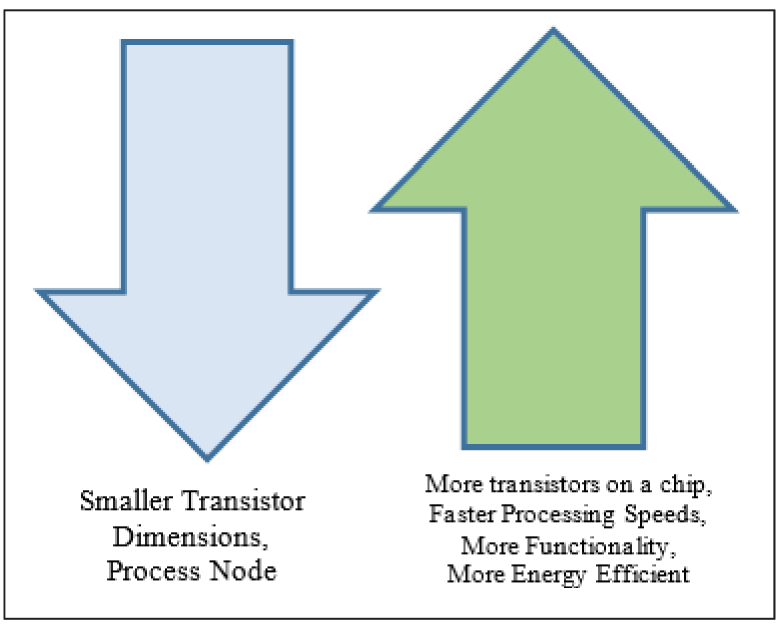

Figure 10 Relationship Between Transistor Dimensions/Process Node and Performance

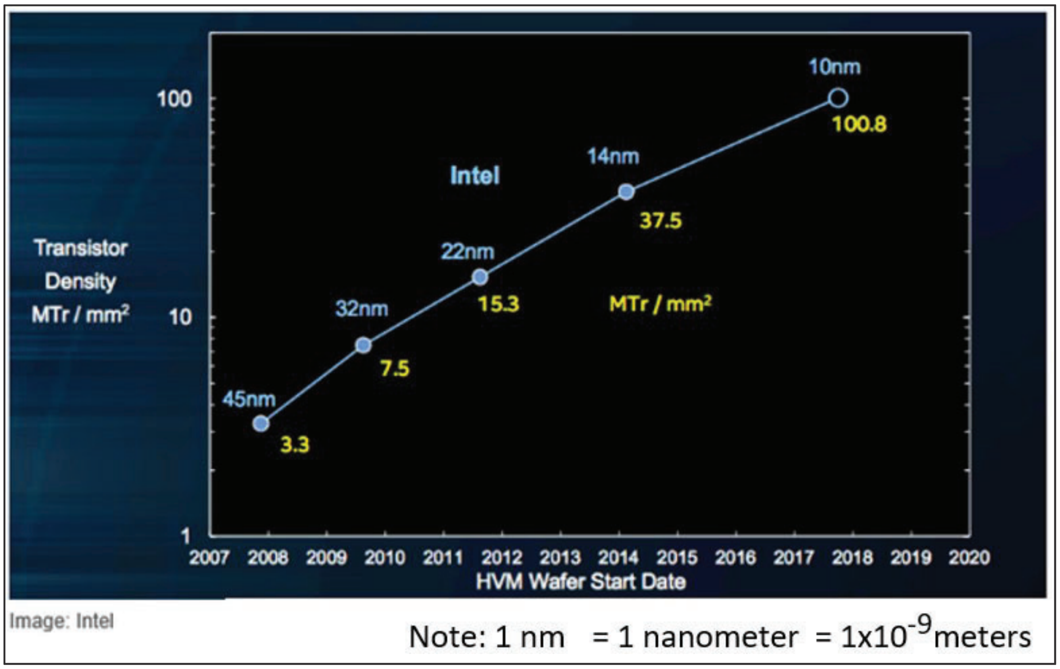

Figure 11 Number of transistor in a square millimeter surface area versus Transistor Dimensions (Process Node) (Million of Transistors / mm2) [Ref 2]

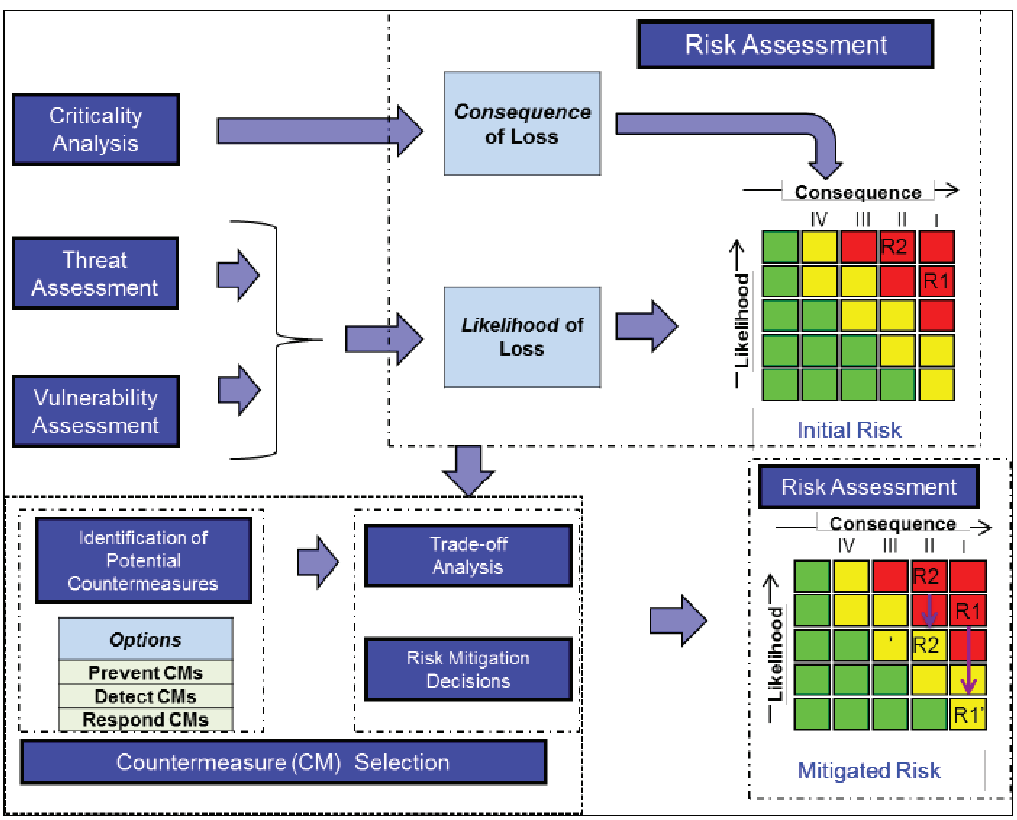

Figure 12 Trusted Systems and Network Analysis Methodology [Ref 30

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