"Innovative Sensing Technologies that Drive Productivity, Quality and Safety"

(as presented by Mr. Kermit Hoffman at the Sensor Expo 2004)

Good Morning. Thanks for coming and I trust you are having a constructive and informative conference. This morning I would like to spend some time talking about the Sensing marketplace and how we, as developers and users of measurement technologies and products, are shaping innovation and helping businesses drive productivity, ensure quality, and meet safety and security requirements.

I wanted to start the presentation off with a well-known axiom that has been often repeated…just to get our creative juices flowing: "**You cannot manage what you cannot measure**". This quote is often attributed to Bill Hewlett of Hewlett Packard who passed away a few years ago. I thought it was worth sharing because it really captures what we, as manufacturers and users of sensing solutions, are all about.

Why do develop a sensor to measure this or that parameter? It's all about someone saying, "Well if I could measure this **particular** parameter in this **certain** fashion, then I could do something, I could take some action that would benefit me." Think about…"if you can sense this particular parameter, then I can do something".

That's pretty powerful. The ability to provide sensing solutions, allows a user of that information to take action, to make decisions, to better their process, to make their plant or environment safer, to produce a better product, to make the product more productive…*powerful stuff*. The world of sensing is as exciting to me personally as it has ever been. I foresee the demands of the world sensing needs really taking some gigantic steps forward in the coming years with MEMs based sensors, Nanotechnology-based materials and several other exciting technologies right on the edge of just breaking out with some fantastic products.

What I would like to focus on today are the trends, drivers, and technology in relationship to how they are affecting "users" and " consumers" with respect to productivity, quality and safety. I will try also to bring in some real-world examples to illustrate these points. At the end of my presentation, I would then like to open up the forum to address questions from the audience if time permits.

From our vantage point, these 5 areas are clearly the main drivers of innovation. While there is much discussion about what is and is not a Smart sensor, there is no doubt in my mind that sensors are clearly more smart today then they were 30 or 40 years ago when the thermistor first began replacing the bimetallic strip and the push towards electronic sensors was on. Today, you can find integrated sensors, which are fully compensated with integral electronics that are embedded in the wing of an aircraft, and communicate digitally via a wireless link to alert ground crews of high stress conditions. I hope to show you advancements like this throughout this presentation, especially in the context of productivity, quality, and safety.

The world of economics largely revolves around productivity; certainly GE does push toward higher worker/asset productivity. Again, it all comes down to what you can measure, how much cost/effort it takes to obtain the measurement, and how practical it is to act on the outcome. But lets focus on the key areas here…product development, design and mfg, and the end user experience. By product development here let me be clear. I mean the engineering time required to design a petrochemical plant or an automobile. The specific task of designing the sensing systems is sometimes outsourced, but this is only because the systems have historically been difficult to bring together.

More than just the difficulty of bringing the whole system together, customers struggle with the need for flexibility in the design cycle. Often we get last minute panic calls to combine the sensing systems, incorporating a sensed quantity that was omitted when we first scoped out the program. Sometimes this is simple to do, as there is ample space available, but for some specialized systems, like for medical or automotive applications, these types of changes can lead to costly delays.

Beyond flexibility, one of the big demand trends in the market place that we are seeing as GE Sensing is that our customers are looking for more than just the sensor element. Customers who are building products or supply product to other higher-level customers are not trying to be experts in sensor technology integration. They are asking more and more for sensing elements with integrated printed circuit boards; and beyond that for sensors in ASIC packages…and then beyond that to even more complete packages that may encompass custom sizes, footprints, signal output, materials, packages to withstand certain environmental needs.

This trend is, in turn, forcing the sensor supplier to become a more full-spectrum supplier with additional capabilities and skill sets. These are what most people are calling smart sensors. The smart sensor is really a construct of a digital plug and play sensor. Sensors Expo has a long history here, which I am sure there is no need to repeat. But let's just say that both customers and suppliers are starting to get the message. There is a large installed base that slows down the introduction of any technology change, but I think that we are on the right track now. Along the lines of simplicity, what is better than a fully integrated, stand-alone system?

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In time, you will see a reduction in the middle ware between the sensor and the actuator, as these systems become more integrated, and more autonomous. Lets move on to the next step in the product cycle: design and manufacturing. Here the name of the game is product cost and this is where we square off with our friends in purchasing. We know the drill, and it is a healthy part of a robust economy.

But what is not readily obvious is that a more expensive sensor can in fact dramatically reduce the overall product cost. This can be due to fewer parts, less weight, reduced installation time, and many others. The one I find amazing is the amount of wire in an automobile: nearly a 50-fold increase since the end of WWII. I would even venture to say that a car is now a piece of electronics with a steel frame around it. And a power plant or operating room is no different. But beyond the smart sensor interface, there are more things that we can do. For instance, lets start by getting more information from a single installation point. For this I want to measure more than just one quantity. When practical, this is a real cost saver.

Installation costs are also greatly reduced from conventional installations by the use of digital communication systems, especially those where power and digital communications are supplied on two-wire systems. A step beyond that is wireless communications. Wireless installation completely eliminates the physical layer of the information transfer system. When these sensors are connected on a digital network, we need to allow the sensor to diagnose itself or the process it is monitoring. Odds are that this sensor has been used in this application before. Why should the end user write all of that software? Why would you really want that latency and overhead on the main process control? Instead, we should distribute these tasks out to the sensors that are close to the process, and use centralized systems to view and determine central trends.

The next important productivity step is adaptive diagnostics on the sensor or instrument. This may involve the instrument “understanding” by some means how it is installed and adjusting itself accordingly during commissioning and start-up. And finally, enable remote or internal calibration.

But while these reduce the system and installation cost, they are beginning to hint at the last category, which are costs for the end user.

End user costs are certainly one of the ultimate productivity drivers for all of us. We see sensors being applied for two main areas: condition-based maintenance, and tighter process control. Both have enormous implications with respect to asset utilization and thus a major cost of doing business. Imagine running a power plant during the summer months when your 18-month inspection is due. Can you afford to wait a month? This is the hottest July on Record. Furthermore, you are asked to increase output to 110% of rated capacity, can you do it? You need sensors to give you the knowledge needed to make these decisions. Yet most components today, from motors and switchgear to reactors and turbines are more likely to have preset operating limits than systems asking you if you would rather produce 110% of rated output and replace this component in 3 months or produce 100% output and replace this component within 5 months.

The first step here we alluded to earlier with the smart sensors. That is, the move from full-blown classical analyzers (boxes with a controller, lot's of computing power) with remote and possibly multiple sensor inputs to products that are SMART transmitters (the sensor with electronics and computing power and standardized digital protocols for power/connectivity). Here is another view of this, but from the end-user side.

The market desire for instruments to move into this newer format is based on the need to "blow-out" the number of measurement points. In the classical case, the product would need an analyzer shelter or instrument rack for the controller. With field devices, just mount them right next to the sample point and wire them up to the digital system. At the lower price point per measurement, the user benefits from more measurement points and therefore more information / better control of their process or application – thus the quality of their process / application is better known.

The corollary to this in the control system, especially with SMART buses where devices communicate on peer networks (wired or wireless) directly with one another is that there is added – value from the field device and a reduction in the value of all the middle-ware to help the system communicate with the control system and even on the control system.

It doesn't take a great leap to imagine that these small transmitters could then be made wireless. Here is one view of how a plant-wide network could be established. Remember that not all sensors are used to evaluate the main plant output, say for example a polymer. Most of the sensors are really needed to diagnose the supporting infrastructure. In this example, we are looking at motors. The ability to monitor the health or condition of the component is just around the corner for us. In fact, there are several products on the market today. I think there is much more to come down the road here.

Not all productivity solutions have to be permanent installations. In fact, just tools that can make troubleshooting more effective can have a large savings. This new product is one such example. We have all driven past a large refinery or in Detroit, a large automotive plant - miles of busbars, countless motors, and switchgear rooms. When part of the facility begins to trip on under voltage or current spikes, it is often very difficult to determine the root cause. Yet one common culprit is that connections on motors and busbar begin to loosen over time as the load increases and decreases. A very proactive plant today may call on a vendor to do a thermal scan of all of these areas and evaluate the status. While this can be effective, it is often the case that many of the important areas cannot be safely accessed while under power, meaning that this approach only has limited utility. In addition, what are the odds that the condition will really manifest itself during the scheduled visit?

Instead, what is needed are a suite of simple, portable, sensors that can measure the temperature of a bearing or motor connection or a busbar joint from a safe distance, using infrared, and then wirelessly communicate this data back to a central station. Now trends can be evaluated over a period of days or weeks, and the condition of the equipment can be accurately assessed. These sensors could then be left in place, or moved to another location in the facility. Again, not the only solution, but a concrete example of how some new sensors will drive productivity for the end users.

The Second Area I want to address is Quality. There is a silent revolution underway in the area of quality of sensors. A big trend in the market place is a quantum shift in the sensor accuracy, reliability, repeatability and stability. One of the banes of the sensor industry, calibration is on its way to be relegated to second place. Thanks to improvement in design and quality, lifetime calibration is a phrase customers are expecting. Once you have sensors, which meet these characteristics, a whole world of applications open up where field replacability is no longer an important attribute. The revolution I talked about earlier, the step change in the MTBF of the sensors are making this possible. 5 Years ago, you would not even think of these applications. The quality levels are making this a reality.

With the integration of new materials, and the fact that quality levels are where they are in harsh environments, stable and adaptive sensors, increases the customer capability for a sensor. With the integrated intelligence, sensors are no longer actuators or sensors, but an intelligent device, that can learn from the past data, adapting its control laws, communicating on their own to adjacent sensors to auto calibrate each other. Applications such as these are a reality today, the quality levels of today's device makes this possible.

Some examples of what I am talking about will make this clear.

Today we will have cars that will sense the temperature around the driver sensed by infrared, measuring the humidity (internal and external), measuring the external air pollen and other gases, and automatically adapt and control the air conditioning, vent louvers, external air input to place the driver at the optimum creature comfort level breathing the best air possible. An independent system would control the comfort of the passenger or be running at a nominal level if the passenger seat is empty. I will also tell you that the sensors involved may be wireless to reduce the number of wires within the automobile, greatly reducing weight. Again, with the extremes of an automobile engine compartment, a system such as this is not a wild dream, but almost a reality. The quantum jump in quality makes this possible.

A different dimension of quality in sensor is the integration of multi measurand multi technology sensors. In the retail or grocery world, there is strong interest in being able to log the health of goods as it had been moved from the producer to the store shelf. Very shortly you will see RFID enabled single sensor with a MEMS based sensor capable of measuring temperature, pressure, shock, humidity, NOx and other gases all in the same sensor. With proximity wireless communication, every time the palette goes through a checkpoint, the extremes the shipment went through will be transmitted. Thanks to the RFID tagging, the retailer not only will be able to track the shipment, but will be able to have a running record of the key variables from the time the container was locked to receipt on their door steps.

Have you wondered whether the frozen fish you are buying at the supermarket did not undergo accidental thawing and refreezing or the shipper of your precision instrument did not accidentally subject your instrument to a sudden 4G shock? With the integration of MEMS with other electronics, these sensors are a reality today.

One of the important aspects of quality in the sensing products we sell involves the calibration of those products. As a manufacturer, we invest heavily into metrology labs and calibration systems at the factory/production level to ensure the product we are shipping is calibrated to national standards like NIST, NPL, ILAB, and others.

In addition, once our sensors and instruments get into the field, customers look to us for solutions for field calibration such as portable field calibrators as shown here.

Above and beyond that, we focus heavily on instrument systems that come up with innovative means to calibrate themselves internally against reference gases or even more advanced, use sensors that validate themselves. The quality and design capability really make the customer say “Sensor, Heal Thyself”

The entire qualification in the medical world is gated by batch qualification. The diagram on the right shows how the lab time gates the qualification process. The dark green is really the actual production time, while the rest is cleaning and waiting for the lab to deliver the result. This slows down production time effectively limiting production or the time to market of a new drug. With the high quality of the sensors, we can now elect to move the lab to the process factory floor. Instead of making something and waiting for the lab to say yeah or nay, the lab could be integrated with production through quality on-line test capability. This will significantly reduce the manufacturing cycle time reducing the cost to the end customer.

I have talked about medical manufacturing in this example, but the thought is applicable to the entire petrochemical world. Comprehensive on line testing eliminates the need for “lab” time. You can visualize a world where taking a sample and send it to the lab will be a thing of the past.

Well, so far we’ve covered the sensor industry from the standpoint of Productivity and Quality. But there is a third element that is driving the sensor industry and that is Safety. Safety’s impact on business and the sensor market is a direct result of our society’s increased awareness and viewpoints in regard to protecting our environment and our families. Our society continues to be influenced by a number of external forces that drive us, as consumers, to demand safer products and safer processes that manufacture these products. Some of the external forces, shaping our views toward safety, include **litigation** trends, **public awareness** and world events, **technology availability**, and the primary driver is **government mandates** and regulations.

For example, trends in **litigation** has increased the attention to safety and monitoring systems, to not only to minimize a potential financial risk, but a company or individual can also reduce the cost of insurance premiums to provide a financial benefit. Similarly, another external force driving safety is the increased **public awareness and world events**. Speed and availability of information along with the focus on security has driven consumers to be ever mindful and aware of the environment around them. Although litigation and world events are shaping the views of society, another key driver leading to a focus on safety is the **availability of technology**. Technology has enabled the development of many safety features that were once cost prohibitive or technically unattainable. The advancements in electronics and computing power, as well as, the development of the "information age" has created a mindset in society of constant real time reliance on added safety features and information in everything we purchase – from cars to home appliances.

Finally, the primary drivers to increasing safety and, therefore the use of sensors, are **government mandates** and compliance with **industry body requirements**. In many cases, these regulations are developed in response to an occurrence or re-occurrence of an invite that was harmful to the environment or individuals. Additionally, the regulations are a requirement of doing business in a particular industry sub-segment. Within these sub segments, there are a variety of industry bodies that manage and certify that products and processes are in compliance with regulations. A small sample of these US based or international bodies are listed which are recognizable to many of us here today. It's these external forces that shape and manage the safety views and regulations that in turn, drive futher uses of sensors and sensing systems. While society continues to increase their focus on safety, what does that really mean for all of us in the sensor industry anyway?

Safety is driving the increase in the number of sensor systems employed but also the complexity of these systems. As more and more mandates and regulations are established, the industry is forced to **detect** more conditions to enable compliance to these regulations. And, for us the sensor industry, we see sensors and sensing systems as the enabler to **detection** which then allows for the **prevention** of an undesirable event, **prediction** that an event will occur, and if necessary **protection** in the case that an undesirable event has occurred.

Whether the sensing system is used to prevent the undesirable event from occurring or it is used to detect that an event has occurred, the goal of these sensing systems is to protect our assets (car, homes…), our environment (air, water…), and our families. In all cases sensors are the core enablers to a safer world.

Let's look at few examples where government mandates or consumer wants have driven the increase use of sensors in the name of safety. The automobile is one of the largest employers of sensing applications driven for the need for increased safety. As you heard from Don Runkle yesterday, sensor use on vehicles continues to grow and with the technology advancements in electronics and communications more safety features are saving lives every year whether is through the use of air bags or anti-lock brakes.

The 2 areas I want to touch on is the use of **tire pressure monitoring** and **driver aids** that increase safety. Tire pressure monitoring is a high growth sensor application in response to tire failures due to under-inflated tires. This application is now mandated by the adoption of the TREAD Act in the US and will require future vehicles to monitor the pressure of each tire and provide feedback to the driver. Prior to the regulation, tire pressure systems were found on high-end vehicles or vehicles with run flat tires as this was required to inform the driver of a low pressure (as run flats, by design can be driver with little air pressure for limited miles).

On the surface, the sensing of tire pressure real time may not be overly challenging. But when you dig into the problem, you quickly understand that this safety application is enabled by a number a different technology advancements. For instance, since the sensors are **embedded** in each wheel, the use of wires to power or communicate with the sensor is not possible. That has required that sensors be created to that communicate **wirelessly** with the receiver to display the tire pressure to the driver. Additionally, each sensor needs it's own power source capable of performing for 10 years. Not only is this challenging for the batteries, but the sensors used must be low power and be "on" only for short periods of time to conserve energy. This requirement, plus low weight and small size, has made the use of MEMS pressures sensors ideal for this application. Additionally, MEMS are being employed to produce accelerometers to enable the turning "off" and "on" of the sensing to conserve power.

It is through the use of this technology that future vehicles will be safer by employing direct Tire pressure monitoring systems – therefore preventing accidents and protecting us from tire failures due to under inflation. A second example of safety features that is driven more out of conumer convenience than mandates is that of **drive aids**. These sensors often employ technology that has been in existence but not cost effective enough in the past to employ on automotive vehicles. Three emerging applications that aid the driver in preventing accidents are: **back-up sensing, blind spot detection**, and **active cruise control**.

Each of these aid the driver, by sensing the environment around the vehicle to assist the driver in preventing accidents. Many of these use **radar** or ultrasonic technology **borrowed from the military** to *predict* and *prevent* accidents. For instance, the back-up sensors warn the driver of an obstacle and it's relative distance to the vehicle protecting both the bumper and a bike that was left in the driveway by children. Whether its preventing accidents or assisting the driving parking or automatically adjusting the cruise control, **consumer wants** are adding significant growth to the **safety** sensor market, in addition to the **mandated** applications like Tire Pressure Monitoring.

Like the automotive industry, the food supply industry has also experienced a recent focus on increased safety in the food supply chain. One well-known example of this is the outbreak of mad-cow disease and its trickling effect to regulations on the industry meat production, handling, and preparation. For instance, more real time monitoring is being done on the meat supply from "pasture to plate". Sensing systems on farms can monitor the **cows "health**" by **wirelessly** communicating the cows temperature and other vital signs from tiny **embedded** sensors in the animal to a receiver. This sensing system can ensure that only healthy cattle are delivered to the slaughterhouse, but these systems can improve the productivity of the farmer as well by providing data to manage growth and reproduction cycles.

Following slaughtering, **shipping containers can be monitored** to ensure that the meat was stored and transported properly. Sensors can provide data regarding the cargo and then systems can upload this information to main computers for tracking purposes or use this information to change the environment of the trailer (ie: make it colder) therefore preventing spoilage and providing safer meat to the consumer.

Finally, regulations at **restaurants to monitor meat temperature** before it is served are driving safety in food preparation and also the use of sensors. Sensors and data loggers can measure and monitor meat temperatures, log the data, and enable more efficient and accurate enforcement of regulations on restaurants -- in the end, ensure only the healthiest of food is provided for consumption and therefore protecting us.

When we talk of **SAFETY**, we cannot forget about the **ENVIRONMENT**. A lot of what we do in the development of sensing solutions is driven by the need to make sure we don't pollute or otherwise endanger the water we drink, the air we breath or the soil we live upon. Sensing solutions revolve around measuring how **much** of a certain component is used or released into the environment and **exactly what those components are**.

For instance, Today we measure the flows of stack gases, vent gas, flare gases and their components as they are released into the environment for both regulatory reporting and for use in trading of emission credits... tomorrow, we'll have to measure in greater detail, to a higher levels of detections, with greater frequency, with greater reliability (or up-time of reporting)…we'll also have to measure things we currently don't measure or don't measure well…for example, mercury measurement in coal-fired power generation is not currently monitored by any type of reliable, rugged online analysis…however, public interest in mercury contamination and pollution is almost certain to spawn eventual regulations requiring this activity…

As with the other examples we have presented today, **protecting our environment** -- **safety** in our environment -- is mandated and driving the use of sensors. With further technological advancements, more real time detection and monitoring will enable **prevention** of harmful contaminants entering our water, air, and soil.

Rather than show a technology, I am highlighting a manufacturing / refinery / chemical plant burning a flare header (visualize driving through NJ or Texas past a big refinery and the flares are all burning...anyway, I found a decent enough picture... I kept the bullets to a very high level, but the point is that a lot of sensing technology revolves around the environment - monitoring stuff that gets into the air, water, solids that come out of a plant.

The convergence of technology combined with the transparency of operations, requires clear and concise visibility into better data. Today we have touched on several technologies and applications that our industry is experiencing… all impacting improved productivity, better quality and ensured safety. I wanted to end to my talk to today with the thought that I touched on at the outset of the presentation… that “you cannot control what you cannot measure”. But having data is not enough.

We need to turn data into knowledge. Its not enough to know that you have a cargo trailer, you need to know whether the trailer is empty or full, en route or stranded, in short whether it is utilized or idle. This is what I mean by resource management. For impact analysis, consider a utility trying to run at 110% rated capacity to satisfy demand on the hottest July day on record. Being able to accurately predict the reduction in service interval or the cost implications of this action is critical to making an informed decision in today’s environment.

Finally, think about a case where a bulldozer is rapidly approaching a pipeline. Understanding whether the driver is trying to park or in fact attempt something significantly worse is the type of situations assessment that requires a combination of sensor data, historical data and domain knowledge. This is the future of sensing to me.

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