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Inside

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Hi-Tech Equipment Reliability A Practical Guide for Engineers and the Engineering Manager

By Dr. Vallabh H. Dhudshia
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High-Tech Equipment Reliability Series

WWK recently received permission to reprint sections from Dr. Vallabh H. Dhudshia's book, *Hi-Tech Equipment Reliability: A Practical Guide for Engineers and the Engineering Manager*. This book, first published in 1995, is now out of print but still provides useful guidance to the equipment engineering community as they strive to improve cost of ownership (COO).

Dr. Dhudshia has been an equipment reliability specialist with Texas Instruments and with Xerox Corporation. He served as a Texas Instruments assignee at SEMATECH for three years. Dr. Dhudshia received a Ph.D. in IE/OR from New York University. He is an ASQ fellow and a senior member of ASME. He has developed and taught courses in equipment reliability overview and design practices. He is an affiliate of WWK, specializing in reliability consulting.

In this issue of Applied Cost Modeling we are reprinting portions of the Introduction and the complete text of Chapter 1. We hope that you find the information in this series useful.

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Editorial Board

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Calendar of Events

March 2007

21-23 **SEMICON China**
New International Exhibition Centre
Shanghai, China

April 2007

23-25 **Strategic Business Conference**
Meritage Resort
Napa, CA

May 2007

8-10 **SEMICON Singapore**
Suntec International Convention & Exhibition Centre
Singapore

14-16 **Global STC Conference (GSC)**
Marriott Napa Valley
Napa, CA

14 **WWK presentation at GSC**

July 2007

17-19 **SEMICON West (WWK booth #2716)**
Moscone Hall South
San Francisco, CA

19 **Understanding & Using Cost of Ownership**
Marriott Hotel
San Francisco, CA

Introduction

Reliability has been widely used to measure equipment performance in military and commercial industries since the early 1940's. Movements to track high-level matrices, such as Overall Equipment Efficiency (OEE) or COO, are more recent developments. Since all such matrices rely heavily on reliability metric, they do not dilute the importance of the reliability discipline. On the contrary, they enhance it.

Today's highly competitive, global market environment demands an optimum level of reliability in present and future products/equipment. Customers expect and, in some cases, competitors force a high reliability level from manufacturing organizations. At the same time, the complexity of most equipment is continuously increasing. These influences are driving ever-higher reliability modules and components just to maintain the same reliability level.

To make a reliability improvement program effective and achieve a world-class reliability level, everyone in the organization—not just the reliability engineer—must play his or her part. Usually, however, not everyone is equipped with adequate knowledge of the discipline to play the part effectively. Reliability engineers understand the implications of this trend. An abundance of available textbooks, military handbooks, standards, and guidebooks use high-level mathematics and statistical theory to help define and clarify reliability discipline for reliability engineers. However, this reliability discipline needs to be understood and applied by everyone in an organization, not just reliability engineers.

This series is a high level overview of equipment reliability. It presents the essentials of equipment reliability without delving deeply into mathematical theory. It is designed for Reliability and non-Reliability professionals. Focus is on understanding equipment reliability metrics, their relationship with COO and how to use them to measure and improve reliability throughout the equipment life-cycle phases including design, manufacturing, and operations. Anyone working with production equipment will benefit from this series, such as equipment engineers, process engineers, manufacturing engineers, service engineers and technicians, all engineering managers, and equipment buyers.

This series will not make a reliability engineer out of you. It will, however, help you become a knowledgeable partner with reliability engineers and others within your organization to help your company reach its reliability goals.

Chapter 1: Brief History of Reliability Discipline

In the early 1940's, equipment manufactures recognized the need for an independent reliability discipline. At that time, emphasis was on the reliability of electronics parts for military equipment. During this time period, the US Departments of the Army and the Navy developed parts standards for a few critical electronics parts.

During the 1950's and 1960's, the discipline saw phenomenal growth on every front. Reliability reached a very high level of awareness and its influence became widespread.

By the 1950's, the reliability discipline expanded to include military electronic equipment and systems. Reliability engineering started to become an important and independent discipline. Leading corporations began establishing formal

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program for reliability discipline, and they drew the attention of professional societies such as the Institute of Electrical and Electronics Engineers (IEEE) and the American Society for Quality (ASQ). Organizations started holding separate symposia on reliability discipline. At the same time, the Advisory Group on the Reliability of Electronic Equipment (AGREE) was established and became very active providing direction and guidelines for the discipline, both for military equipment and for commercial products. By the late 1950's, textbooks on reliability started showing up in bookstores.

As the issue of reliability came to the forefront of management thinking, manufacturers began to become aware of the need for reliability program management throughout the life cycle phases.

By the early 1960's, the US Army and Navy were teaching formal courses in reliability engineering. By the mid-1960's, many textbooks on reliability statistics and engineering were published, and US universities started teaching formal courses in reliability engineering. Additional professional societies were established to cater to the growing interest. At this time, reliability discipline began including the reliability of mechanical parts.

In the 1970's and 1980's, reliability discipline spread throughout the most of commercial products. Reliability improvement programs became more formal, well organized, and documented. High reliability level became one of the customer's requirements. It also became an instrument for manufacturers to compete in the global market place. Focus was also directed on the cost of achieving a reliability level. This led to life cycle cost and optimum reliability level with minimum life cycle cost. During this time, equipment and systems became more complex and their operations became more software dependent. These changes led to a need for reliable software. As a result, software reliability emerged as a part of the reliability discipline.

In the late 1980's, the focus of reliability improvement efforts shifted from screening and inspecting to proactive activities such as designed-in, built-in, and managed growth. This change moved many reliability improvement activities to the beginning of a product's life cycle, at the design and development phase. It was during this time, too, that manufacturers realized their parts suppliers and customers could play an important role in achieving reliability goals. Instead of being simply their supplier's customer and their customer's supplier, they started partnering and cooperating with suppliers and customers for mutual gain. This partnership led to an early involvement of parts suppliers and product customers at the design and development stage to implement reliability improvements.

Within their organizations, manufacturers realized that achieving a desired level of reliability is not only the responsibility of reliability engineers, but required involvement of design, manufacturing and field service engineers, marketing; purchasing; and program managers. High-level corporate managers recognized the need for reliability discipline and provided the needed resources. They made the reliability discipline a part of their business system and incorporated formal reliability improvement plans in the business plans.

The relationships between suppliers and customers became even stronger in the early 1990's. Both initiated more joint development programs, increased cooperation, and exchanges of information.

Suppliers started having access to real-life experience data for the parts or equipment they supplied. Manufacturers started reducing their supplier base and became selective when choosing suppliers. Supplier assessment and certification became prerequisites before manufacturers would deal with them. Existing reliability improvement programs became an important criterion for selecting and certifying a supplier. Reliability requirements became an essential part of an equipment purchase process.

In the 2000's, the partnership between customers and suppliers becomes very strong. Use of proactive approach, built-in diagnosis, auto-correction, predictive maintenance, automted performance tracking, and bench marking become widespread.

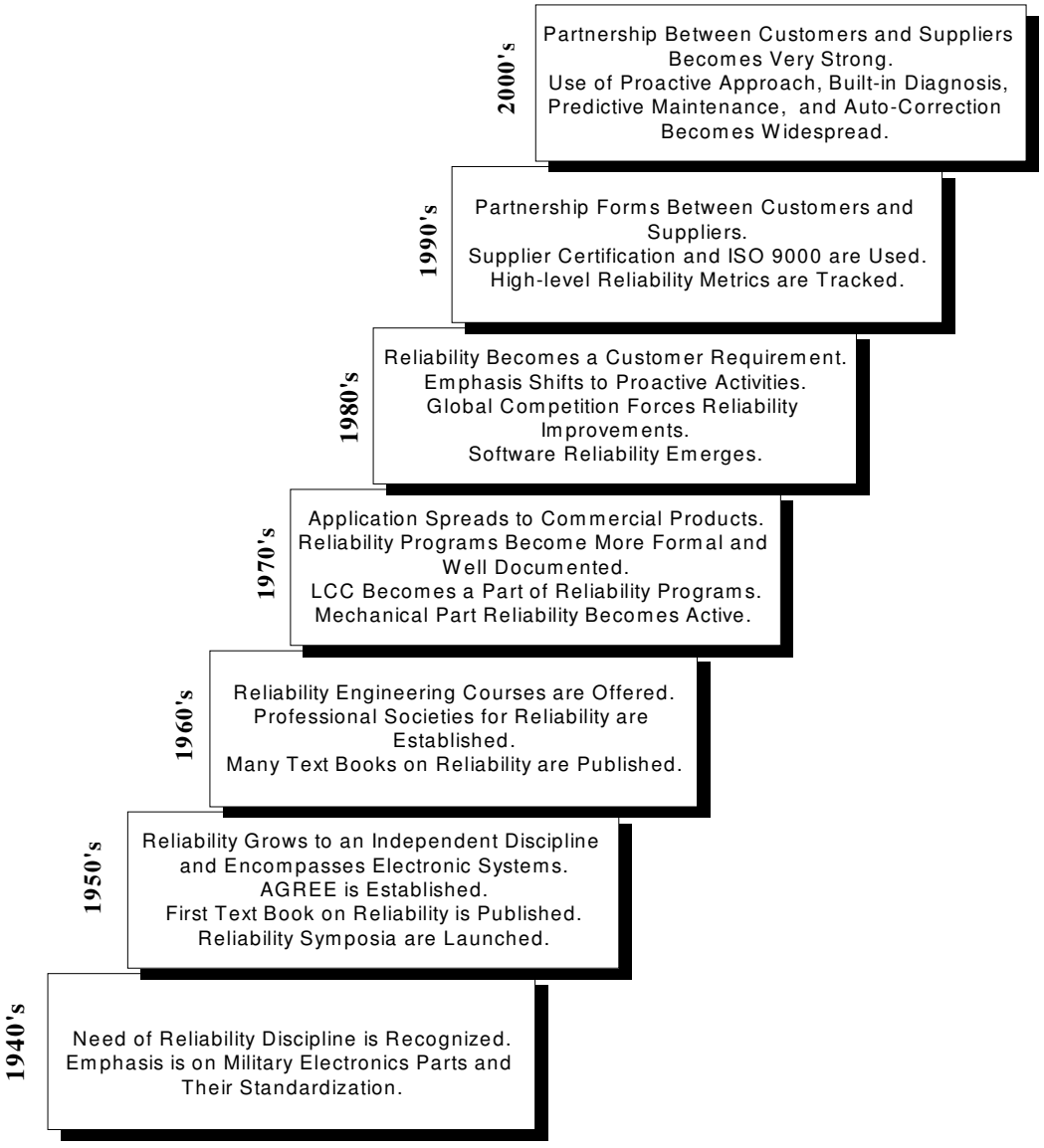

Figure 1.1 - History of Reliability Discipline

Since early 1990's, some equipment users began tracking high-level metrics, such as OEE and COO. Reliability is a key element of such metrics; therefore, emphasis on reliability discipline is ever increasing.

Figure 1.1 shows history of reliability discipline in a graphic format

WWK offers "Equipment Reliability Overview" training based on this book's content. This training can be customized for your organization. For more information, please contact WWK at info@wwk.com.

[Look for installment 2 in the summer edition of Applied Cost Modeling]

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Have Your Customer Audit YOU!!
A Strategic Advantage in Business Relationships

Alan Levine
Wright Williams & Kelly, Inc.

Where is Business Going?

It is a word that tends to make people uncomfortable. Audit. Most typically, audits are executed to comply with some regulatory or control function. For some, it seems like busy work. For others, it means variances getting reconciled. In rare cases, audits uncover highly misleading numbers that result in headline-making consequences. And while some will try to avoid audits at all costs, most see it as a necessity.

A separate trend has been the strong growth of the supply chain management function. Long overdue, there is broad recognition that suppliers are an integral and often a major part of a business. This thinking has caused changes in mindset of how a supplier should be managed. The historic model, where a company beats up its supplier on price, continues to evolve to a belief that win-win relationships are the best approach. This has allowed outsourcing to flourish.

Coupling audits and supply chain management may seem an odd pairing. Instead, it is a new and evolving paradigm. Use an audit to improve your sales! Simply described, by allowing or inviting your customer to audit you, you upgrade your relationship. And that upgrade carries with it numerous benefits to both the customer and supplier.

Larger companies have driven much of this with their suppliers. They have assisted suppliers in a wide variety of areas including quality, tracking and management. Suppliers are often resistant to this "help". A turning point is reached when suppliers understand what it means when your customer wants to "help". It is an opportunity to enhance your business with that customer.

One of the most significant outsourcing relationships is with fabless chipmakers and their foundries. Fabless companies typically see greater than 50% of their cost of goods sold going to the foundries that build wafers, test devices and package the chips. Yet, virtually all of the fabless suppliers are challenged to understand manufacturing costs -- even though their profitability, especially their gross margin, is dependent on this relationship.

Auditing a supplier operation is one effective way to understand costs. But the question remains: should a supplier resist this request or embrace it?

Fear and Reason

Historically, the answer has been to resist an audit. The fears of the customer 'knowing too much' were once paramount. But are those fears justified or do the benefits outweigh the concerns? The answer is the benefits far outweigh the concerns. For example, one fear might be that the customer will think the supplier is making too much money and the audit will be used as a method to cap margins. Such a move by the customer would be foolish. First, it would insure that the supplier would not let another audit occur. And since cost structures change frequently

in this industry, a once and done approach considerably limits the overall value. Realistically, the supplier has nothing to fear.

Eliminating the fear is not enough. It must provide value to the supplier. And there is tremendous value.

Start by recognizing that the cost of goods sold IS an important issue to the fabless company. Appreciate this basic fact. The reason they want to understand cost is not a meaningless wish. It is smart business. Reason 1 to want an audit is that you can build a stronger relationship if you value what your customer values.

If your customer has determined they want to go through the expense and effort to perform an audit, realize that you must be a very important supplier. This occurs against the backdrop of a massive trend: Consolidation of the Supplier Base. By using fewer suppliers, companies better understand their suppliers and gain greater benefits. An audit means your business relationship with your customer is being upgraded. If there is no audit, you should wonder why your customer is not interested!

Reason 2 is an opportunity to understand your customer better. And this leads to Reason 3, creation of a significant new barrier for your competitors. This is very powerful. Unless your competitors are willing to perform a similar audit, then you will have strengthened your competitive position. As a key supplier, you should WANT an audit to be a requirement of doing business, because it puts your competitors in a very awkward position. They must also agree to an audit, even without having the business.

Most companies do not have free reign in pricing in the chip market. Through an audit, it can be determined how to better optimize costs and profits. This brings up a concept that underlies the next few reasons, Total Available Profit (TAP). This is the best case profit scenario for the entire supply chain. In this case, we define the 'chain' as the foundry supplier(s) and the fabless chipmaker. Implicit in TAP is an understanding of both costs and revenues. Further, it follows a simple and powerful rule: ***If the 'chain' is not achieving its Total Available Profit, then there is a win-win opportunity where both companies can increase profits.*** TAP can never be understood without understanding the cost structure of the supply chain. Reason 4 is simple. It allows the maximum profit across the chain to be achieved.

Reason 5 follows from Reason 4 by adding market share. While improved margins can be gained and TAP can be achieved, there is also the opportunity to gain market share. By understanding TAP and using it to guide product mix and volume, it is possible to achieve increased profits at both businesses and increase market share. If the customer only knows the margins it has, not the supplier margins, this cannot be done. This is particularly true in price sensitive chip markets or markets where chip prices need to fall below a certain point in order to be incorporated into end-user products (cell phones and laptops under $1,000 are end markets where chip prices determine what gets included).

Reason 6 is it enables a fair basis for sharing of cost improvements. The two companies may see differently on the benefits of cost reduction. The customer is not interested in the supplier

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pursuing cost reductions unless there is a benefit to the customer. For the supplier, cost reduction is a fabulous use of resources if it keeps all the margin improvement. It is better if these programs can be mutually beneficial so both parties have a mutual interest. Again, this approach looks at maximizing TAP.

Reason 7 looks at design trade-offs. The designer at the customer will often have to make trade-offs in the product design. One example is a trade-off between die area and interconnect layers. A good understanding of costs means the better choice can be made.

Reason 8 looks at the competitive situation of a fables company. Consider three large makers of devices. One uses their own fabs. One has fabs and also outsources. The third only outsources. It is obvious which of these companies would have the greatest difficulty understanding wafer costs. Which means it will have a more difficult time making good choices about manufacturing trade-offs. Realistically, this situation will never be able to achieve the TAP without an 'audit-level' understanding of operating costs. This places it at a competitive disadvantage.

This brings up a series of related issues, not all relevant to every situation, but certainly common. The larger fabless companies continually look at whether an investment into a fab makes sense.

Reason 9 sounds simple. By understanding operating costs, it makes that investment decision easier. Since the fabless company does not own process knowledge, it is most likely to consider capital to be invested with its supplier. The foundry needs large amounts of capital to build its fabs; assistance from a key customer is a win all around. While an audit gives a significant barrier to competitors, investment in the factory is an overwhelming barrier.

Reason 9 can play out in different ways. Foundry spending in 2006 was soft compared to other market segments. However, key customers might be willing to assist in the purchase of new capital if they could see the cost benefit for their specific opportunity. A foundry might be conservative about an investment, but since it is effectively 'insured' by the customer, they will be able to proceed. But this can only be considered if the customer has a reasonable understanding of operations.

Recently, a large IC provider bought a large fabless company. It is not clear if this is the beginning of a trend. However, the new owner will need to determine if the foundry relationship is appropriate or if it should consider internal manufacturing. The foundry is in a position where it needs to protect its business. By opening up through the audit process, it can establish its competitiveness and willingness to work effectively with the new owner. By declining an audit, it raises concerns and makes it more likely that the new capacity will be developed internally and the foundry will have lost a significant customer.

Reason 10 is critical. The foundries are at risk of losing business when a fab-based company acquires a fabless company. Protecting this business is not accomplished by a foundry hiding its cost structure. If that capacity is lost to the fab based company, the supplier will have excess capacity and attempt to fill the void created. If foundries find themselves with excess capacity, margins and profits will go down.

After all the reasons given, one would expect the supplier to be begging to be audited. But the secretive nature of organizations and an instinctive paranoia can sometimes overcome common sense. This has resulted in a compromise, based on the assumption that some understanding is better than none. The concept that has attracted attention is to audit multiple factories and combine the results in such a manner that it is not clear who has what. It does give the customer visibility into the fab costs which are so important to their business. And it protects the foundries from exposing their exact costs to their customer. While less than perfect for either party, it does provide most of the advantages without the emotional concerns that could stymie an effort.

Keys to Success

It really boils down to one major item for each party.

The customer MUST recognize that this is about helping both parties be more successful. If used as a blunt negotiating instrument, it will not only be ineffective, but it will be counterproductive. If used to better understand the operating cost structure and issues, it will be very productive. This belief, that the project is mutually beneficial, is essential.

From a supplier perspective, they MUST recognize an audit as an opportunity instead of letting fear get the better of them. The supplier is right to seek out this assurance and request safeguards in this process. It is helpful for management not only to provide the buy-in, but explain the value to the organization.

There is one party we have not covered yet, which is the auditing party. It is best to have an audit done by a third party who has the capability and understanding of operations. The third party approach insures that biases are eliminated and keeps the customer from 'too much' exposure. It puts the focus on what matters while removing potential personality issues between the principles. This lessens the fear issue even further. The independent third party approach is an easier and more efficient way to get this done. Aside from the obvious issue of professional competence, the auditor cannot have an agenda. The auditor MUST be unbiased and reasonable in their work.

If these guidelines are followed, the resulting success will be very significant.

Summary

We have looked at the audit process from many angles. The biggest obstacle, fear of sharing information, has been discredited. A customer who misuses an audit's results can rightfully expect to be shut out in the future. Instead, by institutionalizing this business practice, substantial benefits can be continually achieved for both companies. And while a supplier might be nervous at the start, it is a great opportunity to improve your profitability, solidify your position with your customer and create a significant entry barrier for your competitors. It also will help when 'big picture' events occur, such as a change in ownership or a major capital investment decision is under consideration.

The relationship between fabless IC providers and their foundry suppliers is critical. The mutual understanding that can be achieved through a factory audit will prove useful, and may be even be critical, in advancing the business results of both organizations.

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Questions to Ask About an Audit Company

- Has their staff worked in wafer fabs as process and equipment engineers?
- Has their staff worked for equipment and material suppliers to the semiconductor industry?
- Are their staff leaders in the SEMI standards process?
- Are their staff experts in activity based cost management (ABCM)?
- Is 100% of their business based on operational modeling and simulation?
- Is their methodology bottoms up ABCM with no incentive to hide or switch costs?
- Do they have software methodology that is commercially available and has been in use for over 15 years?
- Do they offer their clients the choice of bringing this methodology in-house?
- Have they done this type of work for many semiconductor companies?
- Does their methodology bridge the communication gap between the operations and accountants?
- Do they understand cross-functional cost impacts such as the impact of yield on equipment costs and the impact of equipment reliability on yield - which in turn impacts equipment costs?
- Do they know how to ask the manufacturing and process questions that result in more accurate cost analyses?
- Are they independent, working strictly with operations and management to provide unbiased decision making tools and information?
- Can they correctly allocate costs regardless of historic bias or treatment that often masks actual cost/performance?
- Is all data collected based on actual activity rather than assumed from the standard costing system employed by most companies?
- Are they project oriented seeking to provide meaningful and actionable cost effective answers to productivity and capacity optimization issues?
- Is their expertise in semiconductor manufacturing peerless?
- Are their methodologies predictive in nature, allowing for a view of the future regardless of changes from past operating directions?
- Are they an accounting firm that takes a top down approach to cost concentrating on tax, treasury and compliance issues?
- Does their approach allow for hiding or switching costs based on desired outcomes?
- Do they audit data supplied by existing accounting system, which is rarely activity based?
- Are they 100% consulting and driven to keep clients dependent on their services?
- Are they focused on operational financial management or on operational decision making?
- Do they deal with the data that describes the past and are not typically predictive of the future?

Semiconductor Test Consortium and Wright Williams & Kelly, Inc. Partner to Demonstrate the Financial Benefits of Open Architecture

Alliance to Enhance Cost of Ownership Modeling for Test Floor Operations

February 28, 2007 (Pleasanton, CA) – The Semiconductor Test Consortium (STC), the leading proponent of worldwide adoption of Open Architecture, and Wright Williams & Kelly, Inc. (WWK), a cost & productivity management software and consulting services company, announced today a strategic partnership to enhance financial modeling tools to demonstrate the value of the STC's Open Architecture standards. This work will leverage WWK's existing expertise in the areas of cost of ownership (COO) and overall equipment efficiency (OEE) as represented by its software products TWO COOL® and PRO COOL® for Wafer Sort & Final Test.

"The STC's mission is to support the development and long-term success of Open Architecture," stated Bob Helsel, STC Manager and Secretary. "Open Architecture delivers unparalleled technical and economic performance; is truly enabled for solution development; and provides true multi-vendor interoperability both at the hardware and software level."

"Our work with WWK, a world leader in cost modeling, is designed to support the above goal of promoting the economic advantages of Open Architecture. This will be done using industry accepted economic modeling approaches enhanced to demonstrate the unique attributes of Open Architecture."

"By leveraging our large installed base of TWO COOL® and the sophisticated algorithms of PRO COOL®, the STC can jump-start its efforts to quantify the financial benefits of Open Architecture," states David W. Jimenez, WWK's President. "As an STC member company, we look forward to supporting these important, industry-wide, efforts. We believe that the results will clearly show the economic advantages."

The STC was founded in 2003 to develop a common test architecture that is completely open, documented and supported via solutions available from all ATE vendors. Open to all companies throughout the semiconductor supply chain with a vested interest in the test sector, the consortium is focused on the following goals: formalizing a broadened STC scope with new working groups and specification structure; fostering precompetitive collaboration among industry participants toward development of value-added standards; emphasizing new initiatives, the value of work being accomplished and the contributions to the industry; and continuing STC efforts to fully enable the OPENSTAR® Ecosystem. Today, 47 semiconductor, equipment and instrumentation companies worldwide and 40 university members in Europe, Japan, China and the United States, in addition to 7 STIL users and 5 individuals support the STC. More information can be found at www.semitest.org

With more than 3,000 users worldwide, Wright Williams & Kelly, Inc. is the largest privately held operational cost management company serving technology-dependent and technology-driven companies. WWK maintains long-term relationships with prominent industry resources

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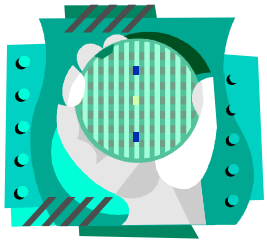
including SEMATECH, SELETE, Semiconductor Equipment and Materials International (SEMI), and national labs and universities. Its client base includes most of the top 20 semiconductor manufacturers and equipment and materials suppliers as well as leaders in nanotechnology, micro-electro-mechanical systems (MEMS), thin film record heads, magnetic media, flat panel displays, and solar panels.

In addition to its professional consulting and market research services, WWK's product line includes TWO COOL® for detailed process step level cost of ownership (COO) and overall equipment efficiency (OEE), PRO COOL® for process flow and test cell costing, Factory Commander® for full factory capacity analysis and activity based costing, and Factory Explorer® for cycle time reduction and WIP planning. Additionally, WWK offers a highly flexible product management software package that helps sales forces eliminate errors in product configuration and quotation processes.

OPENSTAR is a registered trademark of the STC.



Call for Papers: MASM 2007 Conference

The 2007 MASM conference will be held in Scottsdale, Arizona, in conjunction with the 3rd annual IEEE Conference on Automation Science and Engineering (IEEE CASE 2007), sponsored by the IEEE Robotics and Automation Society (RAS). The conference will be held on September 22 to 25, 2007. See http://www.ieee-case.org for more details. The International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM) is a biannual conference that was initialized in 2001 by Professor John Fowler at Arizona State University. MASM2005 was successfully held in Singapore (http://www.simtech.a-star.edu.sg/masm2005/).

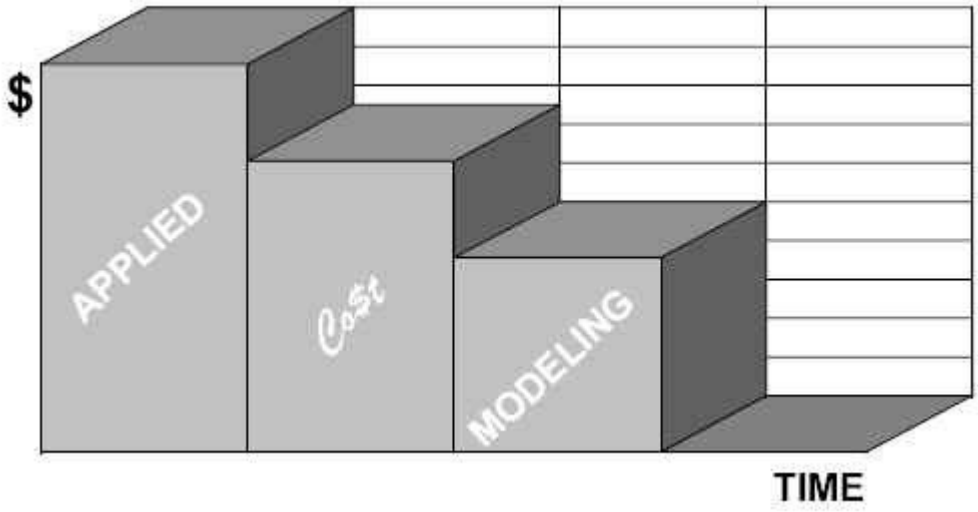
The following text is from the conference call for papers, available in full at http://www.fulton.asu.edu/~case2007/downloads/CFP_IEEE_CASE2007_MASM.pdf.

The fourth International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM 2007) will again be a forum for the exchange of ideas and best practices between researchers and practitioners from around the world involved in modeling and analysis of semiconductor manufacturing. We are interested in any methodologies, research, and/or applications from other industries, as well, that might also be utilized for the semiconductor industry.

MASM 2007 will be a major track of the 3rd annual IEEE Conference on Automation Science and Engineering (IEEE CASE 2007), sponsored by the IEEE Robotics and Automation Society (RAS), which will be held on September 22 to 25, 2007 in Scottsdale, Arizona, U.S.A. CASE is an offspring of the IEEE Transactions of Automation Science and Engineering. High quality CASE papers will be recommended for publication in this flagship automation journal.

Semiconductor manufacturing is one of the forefronts of automation science and engineering. With the emerging highly automated wafer fabrication facilities (fabs), there is a compelling trend to integrate automation with advanced decision technologies in managing factories, logistics, and supply chain networks. On behalf of the IEEE RAS Technical Committee on Semiconductor Manufacturing Automation, we invite you to submit your original, significant, and visionary papers describing scientific methods and technologies that improve efficiency and productivity of semiconductor manufacturing. Topics to be covered include the following (and others listed in the full announcement):

- Factory modeling, analysis, performance evaluation
- Planning, scheduling, dispatching
- Equipment productivity improvement
- Manufacturing execution systems (MES)
- Cycle time reduction
- Data mining for yield and production improvement
- Benchmark and case studies



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