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Inside

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Manufacturing Cost Advantages of "Solar Breeder" Factories for Deployment in Utility Scale Solar Farms

With this edition of Applied Cost Modeling, we are publishing the first installment in a series on the application of cost and resource modeling to crystal silicon-based (c-Si) photovoltaic (PV) supersized module manufacturing.

Introduction[1]

This paper, the fourth in a series, examines a new approach to module assembly based on the concept of supersized 1 kW modules. Utilizing supersized modules (5 ft x 12 ft) and integrated microinverters, this new approach is estimated to save utility installations up to $0.55/W. The paper will conclude with a detailed cost and resource case study comparing two 40 MW module lines, one employing breeder technology and the other producing conventional sized modules.

Conventional PV Module

The PV module is an assembly of electrically interconnected solar cells enclosed in a weatherproof package. The module circuit design specifies the number of cells connected in series, the number of cells connected in parallel, and the frequency of parallel interconnects. The number of cells in series determines the module operating voltage. The cell area and the number of cells in parallel are proportional to the module current output. Any practical series-parallel configuration can be fabricated to meet specific module design requirements.

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[Continued on page 3]

Editorial Board

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Calendar of Events

March 2013

19-21 SEMICON/FPD/SOLARCON China
Shanghai New International Expo Center
Shanghai, China

April 2013

1-4 North America Standards Meetings
SEMI Headquarters
San Jose, CA

May 2013

13-16 Advanced Semiconductor Mfg. Conference
Saratoga Hilton
Saratoga Springs, NY

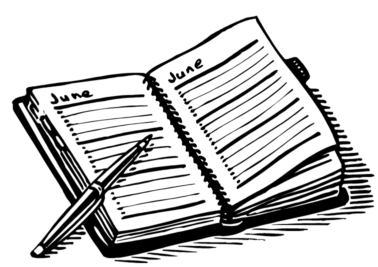
June 2013

16-21 IEEE - PVSC
Tampa Convention Center
Tampa, FL

19-21 Intersolar Europe
Messe Munich
Munich, Germany

July 2013

9-11 Intersolar North America
Moscone Hall
San Francisco, CA



A cutaway view of a module is shown in Figure 1. Tempered low-iron glass is used for the front cover (or superstrate) to provide permanently transparent protection for the optical surface of the module. The remainder of the laminate consists of clear ethylene vinyl acetate (EVA) encapsulant, the cell circuit, a second layer of EVA, a fiberglass sheet, and a back cover film.

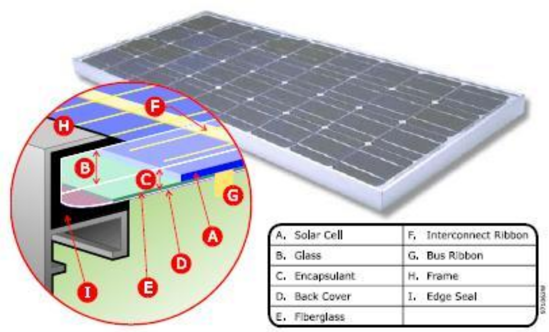


Figure 1: Cutaway View of Module

EVA, supplied in sheet form, is both a transparent soft encapsulant and an adhesive for bonding the layers together. The lamination process is designed to thoroughly remove air from between all layers. The fiberglass sheet prevents the cell circuit from damaging the cover film during the module's lifetime. When the EVA encapsulant is heated for lamination, it melts and impregnates the fiberglass. This provides a strong bond extending from the cell backs, through the fiberglass, to the back cover. A foam tape gasket protects the module edges, where the back cover film meets the glass. This tape cushions the glass panel and decouples it from the module frame to prevent degradation of the edge by daily thermal cycling.

Electrical output leads are brought through the encapsulant and back sheet. The leads go to a junction box mounted on the back of the module. Weather-tight intermodule wire connections are made at the junction box.

Conventional Module Process Sequence

The manufacturing process uses solar cells and module materials as inputs and produces functional PV modules, ready for use. The process, which is shown in Figure 2, consists of the following steps:

- Sorting solar cells into performance groups (i.e., current groups at load voltage) using a cell sorter.
- Washing, rinsing, and drying the glass superstrate.
- Cutting EVA and placing it on the glass.
- Assembling and soldering cell strings interconnected with metal ribbons using an assembler/stringer.
- Aligning and placing strings onto the EVA (previously placed on the glass).
- Completing the module circuit by soldering bus ribbons to connect the strings together and provide output leads at a busing station.
- Visually inspecting and electrically testing the module circuit by measuring its dark current-voltage (I-V) characteristics at an inspection station.
- Cutting EVA, fiberglass, and back sheets to length and assembling them with the glass and module circuit, using an EVA/back sheet layup station, in preparation for encapsulation.
- Laminating the assembly and curing the EVA.
- Completing final assembly, which includes edge trimming, installing an edge gasket and frame, and attaching a junction box.
- Performing a high voltage isolation test to measure the voltage isolation between the cell circuit and the module frame, and testing the frame ground continuity.

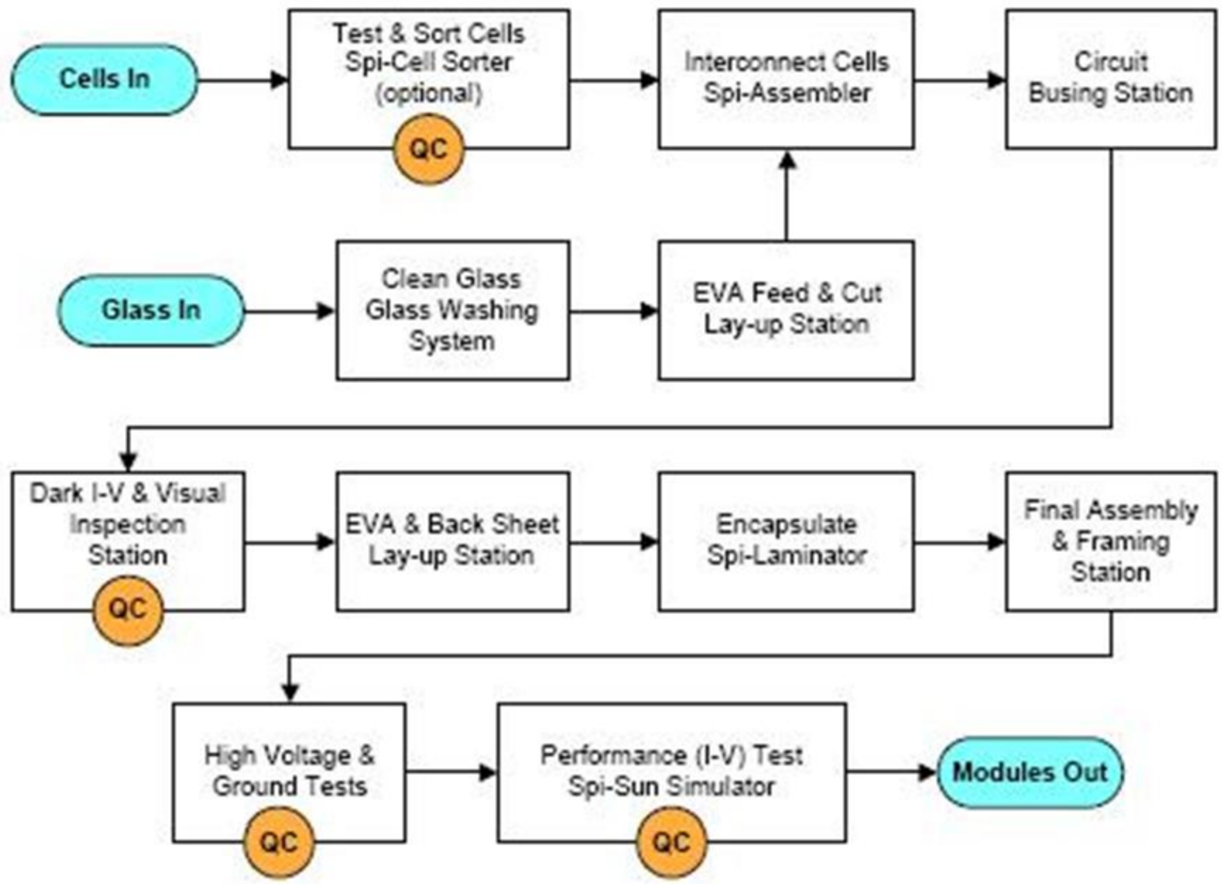


Figure 2: Process Sequence

- Electrically testing the module under simulated sunlight with a sun simulator to measure its electrical performance.
- Visually inspecting the completed module for quality of materials and workmanship.

New Solutions for the Utility PV Market

The solar utility PV market is experiencing significant growth that will continue through the foreseeable future. Utilities are expected to add over 20 GW of solar PV to their generation portfolios by 2020. The rapid growth in market demand is driving development of utility-scale solar projects such as grid-tied solar farm systems of 25 to 200 MW. These farms will consist primarily of crystalline silicon (x-Si) modules due to utility demands for reliability, high efficiency, a proven track record, and demonstrated 20 year life span, as well as overall cost considerations. Cost remains a major consideration in these growth projections, and further cost reductions will be necessary for additional growth to be achieved.

Spire Corporation has been a leading worldwide supplier of turnkey module and cell lines to the PV industry for over 25 years. Spire is currently developing a new solar cell assembler and associated technology for the production of supersized 1 kW utility PV modules. Such larger modules provide significant cost savings by lowering materials, balance of system (BOS), and installation expenses. Furthermore, a single, larger panel-integrated microinverter utilized on the 1 kW modules will provide cost advantages compared to a larger number of smaller units on conventional modules. Total predicted savings are near $0.50/W. This cost reduction will translate into billions of dollars in cost savings over the next decade for this rapidly growing market segment.

Maximum output for a conventional PV module is currently between 230-245 W. Larger modules, up to 400 W, have been recently introduced and are targeted specifically at the utility market. Supersized modules, more than double this size, will provide even greater benefit for PV utilities. However, very large modules are impractical if they need to be transported significant distances. Importantly, the transportation constraint does not apply to the key materials that go into a solar module, the solar cells, which are small, light and can be tightly packed. The transportation complexities for the supersized module provide an incentive for local module manufacturing at the solar farm site or at centralized locations with multiple customers nearby. The expenses associated with building a local factory are quickly offset by savings realized from the larger module design. An important consideration in the rethinking is how to address a factory designed to service a very limited customer and exclusively local customer base. Simply put, the factory can be moved every few years. At the completion of the project, the factory can be decommissioned and the equipment relocated to another solar farm site to continue production.

Supersized PV Module

Spire has created a preliminary design for the supersized module, which will be nominally 5.5 ft by 12.5 ft and made with 240 standard 156 mm x-Si solar cells connected in 10 cell strings. Utilizing cells with a nominal output of 4.19 W/cell (17.2% cell efficiency) will produce a module power of 1 kW. See Figure 3.

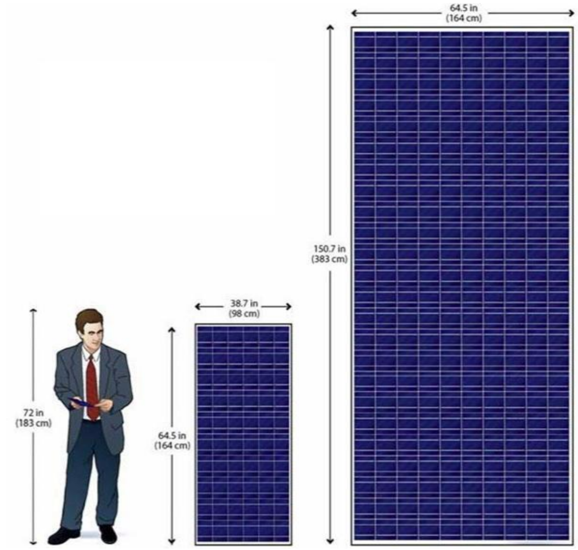


Figure 3: Module Size Comparison (230 W vs. 1 kW)

Supersized Module Process Sequence

The major steps required in the supersized Module Process Sequence are remarkably similar to those utilized in a standard module production line (as listed previously). As currently planned the following items reflect the major differences between the two production lines:

1. Size of Production Equipment – Producing modules that are four times the size of a standard module requires larger Assembler and String Layup, Laminator, Sun Simulator, and conveyors.
2. Increased Automation – Expected to weigh approximately 330 lbs (150 kg), the production line for the supersize module requires a high degree of automation.

A layout schematic for an automated 40 MW line capable of producing 1 kW modules is shown in Figure 4. All dimensional units are in meters.

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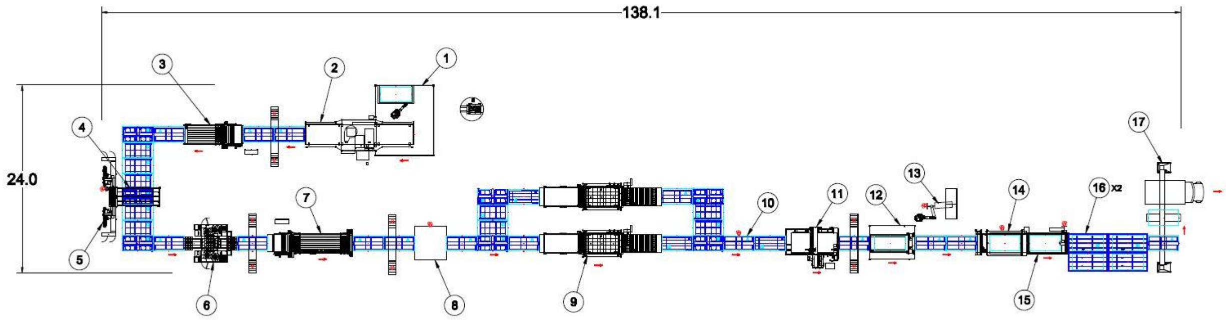

ITEM	DESCRIPTION	QTY
1	GLASS LOADER	1
2	GLASS WASHER	1
3	EVA CUT & PLACE STATION	1
4	STRING LAYUP STATION	1
5	SPI 7000 ASSEMBLER	2
6	BUSING STATION	1
7	EVA CUT & PLACE	1
8	INSPECTION & DARK IV TEST STATION	1
9	LAMINATOR	2
10	TRIM STATION (W/ LIFT GATE CONVEYORS	1
11	JUNCTION BOX ASSEMBLY	1
12	FRAME ADHESIVE APPLICATION	1
13	FRAME LAYUP STATION	1
14	SUN SIMULATOR	1
15	HI-POT TEST	1
16	AUTOMATIC CONVEYORIZED SIDE BUFFER	2
17	UNLOAD STATION	1

Figure 4: 1 kW Line Layout

References

1. For a detailed discussion of the history, standards, and algorithms of COO and OEE, please see D. Jimenez, "Cost of Ownership and Overall Equipment Efficiency: A Photovoltaics Perspective," Photovoltaics International, Ed. 6.

Authors

Mr. Kevin Wolter is the Assistant to the President of Spire Corporation. He has spent seven years working in the clean energy space with much of this experience focusing on manufacturing operations, engineering development, and project management. He holds B.S. degrees in Electrical Engineering and Mechanical Engineering from Kettering University (Flint, MI) and has received his MBA from the Harvard Business School.

Mr. Eric Tobin is currently a Vice President with Spire Corporation. He has been with the company for over 20 years, most recently involved with operational systems development, and evaluation and development of new market opportunities for Spire's solar equipment. Mr. Tobin holds BS and MS degrees in Applied Physics from the University of Massachusetts at Lowell.

Mr. Michael Nowlan is Advanced Technology Manager at Spire Solar, Inc. He has been a member of Spire's technical staff for 33 years, working on PV module and equipment development for 32 years. He currently manages the Advanced Technology Center at Spire, which develops new module designs and assembly processes, evaluates new module materials, provides module process training for Spire's equipment customers, and produces limited productions runs of PV modules for a wide range of applications. He holds a BA in Physics from the University of Massachusetts at Boston.

Mr. David Jimenez is President and co-Founder of Wright Williams & Kelly, Inc., the largest privately held operational cost management software and consulting services company. He has approximately 30 years of industry experience including management positions with NV Philips and Ultratech Stepper. He holds a B.S. in Chemical Engineering from the University of California, Berkeley and an MBA in Finance. He was also responsible for the design of the semiconductor industry's de facto standard in cost of ownership, TWO COOL®. He is a recipient of the Texas Instruments Supplier Excellence Award for his contributions to their cost reduction efforts. For over 20 years, he has been a facilitator in the SEMI sponsored workshop, "Understanding and Using Cost of Ownership." Mr. Jimenez can be reached at +1 925-399-6246 or david.jimenez@wwk.com.

Wright Williams & Kelly, Inc. Conducts 7th Annual Semiconductor Manufacturing Technology Survey

Wright Williams & Kelly, Inc. (WWK), the global leader in cost and productivity management software and consulting services, recently announced the start of its 2013 survey on equipment and process timing in the semiconductor industry. The survey results will be consolidated and provided to all participants free of charge. Participation in the survey is the only way to receive a full set of results. The survey form can be downloaded from the WWK Web site at: http://www.wwk.com/2013survey.pdf.

Last year's survey showed that respondents expect to see the following manufacturing technologies in production no later than 2013:

- Double Patterning
- Source/Mask Optimization (SMO)
- Through Silicon Vias (3-D Integration)
- Through Silicon Vias – Cu & W Fill
- HiK Gate (HfO_2, ZrO_2, etc.)
- Metal or Dual Metal Gate

However, survey respondents did not expect to see the following technologies in production until 2015 or beyond:

- 193 High Index Immersion Lithography
- Direct Write
- EUV Lithography
- Imprint Lithography
- 450 mm Wafers

With more than 3,000 users worldwide, Wright Williams & Kelly, Inc. is the largest privately held operational cost management software and consulting company serving technology-dependent and technology-driven organizations. WWK maintains long-term relationships with prominent industry resources including SEMATECH, National Institute of Advanced Industrial Science and Technology, Semiconductor Equipment and Materials International (SEMI), and national labs and universities. Its client base includes nearly all 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 (FPD), solid state lighting/light emitting diodes (SSL/LED), photovoltaics (PV), and healthcare.

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/Healthcare Commander® for full facility capacity analysis and activity based costing, Factory Explorer® for cycle time reduction and WIP planning, and TCOe™ for energy production project costs (cost/kilowatt-hour). Additionally, WWK offers a highly flexible product management software package that helps sales forces eliminate errors in product configuration and quotation processes.

Call for Papers: 9th International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM) 2013

The 2013 International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM) aims to 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 high-tech manufacturing systems. We are convinced of the worth and importance of the continuation of the MASM events held in Tempe, Arizona in 2000 and 2002; Singapore in 2005; Miami, Florida in 2008; Austin, Texas in 2009; Baltimore, Maryland in 2010; Phoenix, Arizona in 2011; and Berlin, Germany in 2012.

The MASM 2013 conference will be fully contained within the Winter Simulation Conference 2013 (WSC 2013), the leading conference in discrete event simulation. WSC 2013 features a comprehensive program ranging from introductory tutorials to state-of-the-art research and practice. WSC 2013 will take place in Washington, DC, USA. All attendees of the MASM conference will register for WSC 2013 at the same cost. All participants of WSC 2013 can attend MASM 2013 sessions.

We are looking for high-quality research at all levels of semiconductor manufacturing. At the operational level, improved equipment and process control and optimized scheduling and material handling system policies must be studied. At the tactical level, better capacity planning and qualification management are expected. At the strategic level, demand planning, factory economics, and supply chain efficiency must be improved to support the business. Moreover, better integration of decisions taken at the three decisions levels is becoming a must. We are also looking for papers with a focus on the sustainability of the semiconductor manufacturing facilities and the supply chain. Topics may include the development of policies to reduce electricity and water consumption in wafer manufacturing, the metrics to measure the impact of carbon footprint reductions on the global supply chain, the integration of renewable technology in the fab, etc. These various goals will be attained through new advanced control and statistical methods, and operations research and simulation methods. While the MASM conference is mostly focused on the current semiconductor industry state-of-the-art, neither presenters nor attendees need to be in the integrated circuit (IC) industry to participate. We are interested in any methodologies, research, and/or applications from other related industries such as thin film transistor – liquid crystal display (TFT-LCD), flexible displays, biochip, solid state lighting (LED) and photovoltaic (PV) that might also share or want to share common and new practices.

Conference Location: MASM 2013 will be held in Washington, DC, at the J.W. Marriott Hotel located on Pennsylvania Avenue. It is located just 20 minutes from Reagan National Airport.

Paper Submission:
Please follow the WSC 2013 Author Kit to prepare your MASM 2013 paper at:
http://www.wintersim.org
Important Dates:
Deadline for Paper Submission: April 1, 2013
Notification of Acceptance: June 3, 2013
Camera Ready Paper due: July 15, 2013

Recommended Reading

It has come to our attention that long time supporters of operational modeling, Lars Mönch, John W. Fowler, and Scott J. Mason, have a new book titled *Production Planning and Control for Semiconductor Wafer Fabrication Facilities: Modeling, Analysis, and Systems*.

Over the last fifty-plus years, the increased complexity and speed of ICs have radically changed our world. Today, semiconductor manufacturing is perhaps the most important segment of the global manufacturing sector. As the semiconductor industry has become more competitive, improving planning and control has become a key factor for business success. This book is devoted to production planning and control problems in semiconductor wafer fabrication facilities. It is the first book that takes a comprehensive look at the role of modeling, analysis, and related information systems for such manufacturing systems. The book provides an operations research- and computer science-based introduction into this important field of semiconductor manufacturing-related research

The book can be found on Amazon at:

http://www.amazon.com/exec/obidos/ASIN/1461444713/wrighwillikelly

New WWK Article in Photovoltaics International

Photovoltaics International's 19th edition contains a paper written by Wright Williams & Kelly, Inc. and titled "When capacity buys are not an option: Technical trends in c-Si cell manufacturing and their implications." The journal can be obtained at http://www.pv-tech.org at the end of March 2013. The abstract is: Economics will always play a crucial role in the way photovoltaic (PV) technology advances. However, the current generation of products is facing substantial business challenges in the attempt to scale their technologies. This paper is the fifth in a series covering business analysis for PV processes. The methods applied in these papers fall into two categories, cost of ownership (COO) and cost and resource modeling. Both methods examine the business considerations associated with the adoption of new processes, tools, or materials. This is more critical than ever. Near term issues, in some cases the survival of the business, heavily influence today's decision processes. We have tried to identify the areas we think will produce the largest near term paybacks. The areas we have identified are n-type wafers, Al_2O_3 passivation, and copper metallization.

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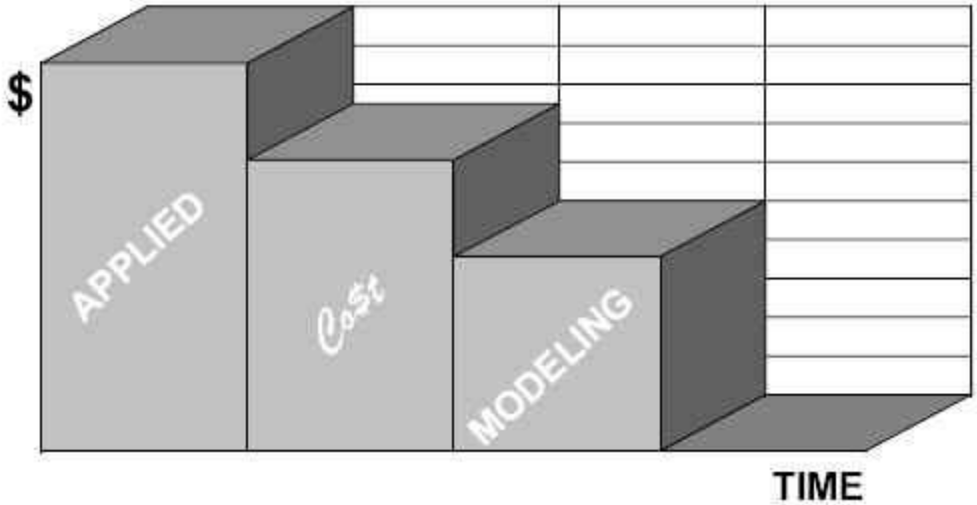
In Memoriam: Mark Allen Stinson, President, WWK Healthcare

It was with deepest regrets that on February 20, 2013 Wright Williams & Kelly, Inc. announced the passing of the President of its healthcare division, Mark Allen Stinson.

With more than 25 years of executive level experience in the private and public healthcare industry, Mark had administratively directed all hospital-based clinical, support, and administrative departments. His expertise also included the research, development, and implementation of market-driven service lines, consolidation/regionalization strategies, Total Quality Management (TQM), safety programs, patient-centered clinical delivery systems, culture change management/stakeholder realignment strategies, and the forging of physician joint ventures. Before joining WWK Healthcare, Mr. Stinson served as President & CEO of Aware Concepts whose mission was to assist healthcare providers in achieving higher quality and efficiency through system(s) integration, strategic facility planning, and operations improvement.

Mark's passion was to help others and in doing so found himself surrounded by an ever-growing and large group of dedicated friends and colleagues. He will be greatly missed.



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