ORCHESTRATING FOUR ATE SUPPLIERS TO REDUCE TEST COST FOR A HIGH-VOLUME RF-IC

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presented at
SEMI Fifth Annual Manufacturing Test Conference
July 1996
San Francisco, California, USA

Biographies

Dale Anderson is Equipment Engineering and Hardware Engineering Manager for CMOS Test Operations at National Semiconductor in Santa Clara, California. Mr. Anderson's primary responsibility at National is to develop and implement new handlers and interfaces into production operations. He graduated from DeVry Institute of Technology in Phoenix, Arizona in 1976 with a BSEET.

Marty Cavegn is a Product Engineer at Johnstech International. Mr. Cavegn specializes in new handler/application interfaces for short contact test sockets. He graduated from the University of Minnesota, Institute of Technology in Minneapolis, Minnesota in 1991 with a BSAEM.

Abstract

When National Semiconductor Corporation (NSC) was planning production for a new TSSOP (Thin Shrink Small Outline Package) part for the commodity wireless market, a task force evaluated alternatives to reduce the cost of test and improve units/hr. NSC decided on a quad-site approach, but when we initiated the pilot program, we discovered that the handler needed wasn't available. Our search uncovered that the required handler was in development. Then we were faced with integrating our new part with a new handler, a new contactor, an upgraded tester, and a new manipulator. We began by planning the systems integration task. A large part of our task involved orchestrating four suppliers through a series of meetings and plant trips over a period of 18 months.

This paper describes:

- How we modeled test costs and units/hr. to decide on our approach.
- The criteria we used for selecting suppliers.
- How we orchestrated suppliers.
- The issues we encountered with systems integration, and how we handled issues.
- Major breakthroughs and accomplishments.
    - increased units/hour (UPH) by 3.5X
    - tested at 2.2 GHz Quad site
    - developed 32 bit parallel interface capable of synchronous & asynchronous parallel test
    - disabled sites on-the-fly
    - device maintained temperature under test

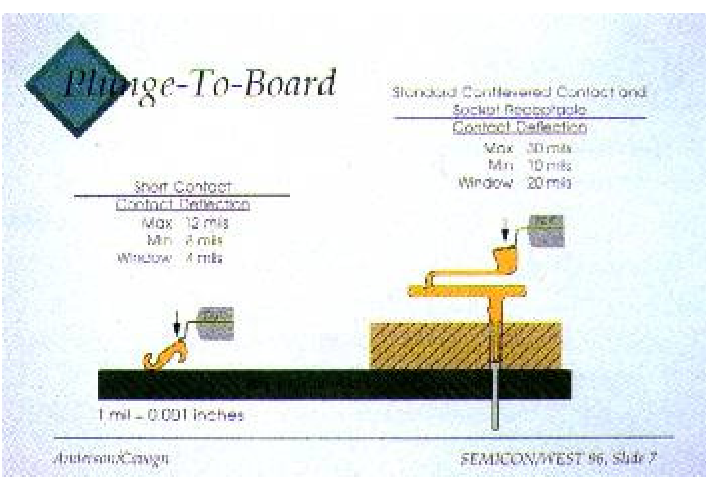
Our purpose in presenting this paper is to describe how we orchestrated result oriented activities with suppliers. We do not attempt to describe the technical details. Rather, we describe the process used, and how this process worked for us at National.

Project Goals
In 1994, the TSSOP device was on a pick-and-place. Our run rate was about $3 million. Our business plan for the commodity market called for an increase in revenue by a factor of 10 in 2-3 years. To achieve that, we would have to increase volume by an even larger factor to offset price erosion. At the same time, we needed an approach that reduced risk with incremental improvements in volume to support the growing business.

NSC Process
At National Semiconductor Corporation we have a process for attacking this kind of project. First, define the needed manufacturing breakthroughs. In this case, that means both increase volume and reduce test cost by a factor of three. Second, survey the market to see what's available to meet our objectives, and run models to project the results we theoretically could expect.

Project Objectives
We felt we already had the needed tester and contactor technology. So the objectives focused mostly on the test handling system. Our target was to reduce test time to about 1.8 seconds. That eliminated pick-and-place handlers because their index times were too high -- a few seconds. We looked at gravity-feed, and from the market survey decided on a quad-site unit that was in development. We felt achieving 0.8 seconds was a reasonable index time for the system. That became one of the objectives, along with production worthiness, low risk and plunge-to-board.

Plunge-To-Board
At National we use the term "plunge-to-board" to mean the ability of the handler system to move the device to the contactor in a controlled, accurate fashion, and with range of motion able to reach the DUT (device under test) board and contactor. We wanted the handler to have the ability to work with the "ideal" contactor -- one that has negligible profile.

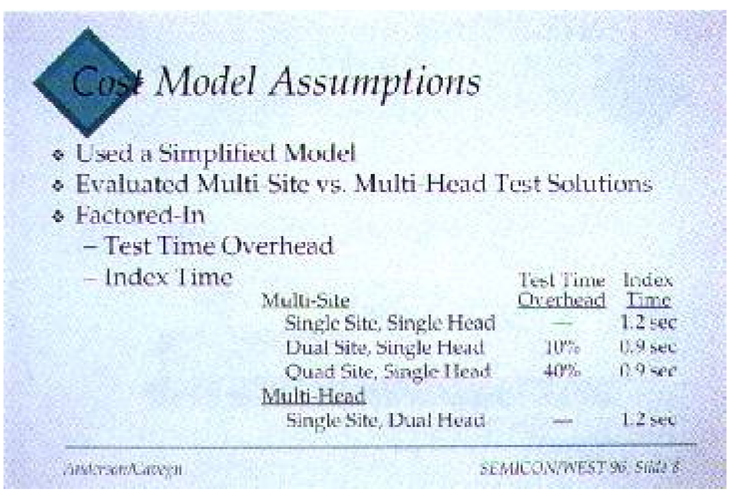


We already had a low-profile contactor, rated for 4.5 GHz, from an earlier project, and were using it on the pick-and-place. No matter how good the handler, we couldn't do this project without the high-performance contactor. The much shorter signal path meant less inductance and higher bandwidth.

However, with these shorter contacts, the handler must operate within a tighter contact deflection window. With conventional, cantilevered contacts, the minimum deflection for continuity is 10 mils, and the maximum to prevent damage is 30 mils, so the window is 20 mils. But with the short contacts we used, the mm/max deflections are 8 mils and 12 mils, so the window is only 4 mils. This is one of the special requirements "plunge-to-board" adds to the equation.

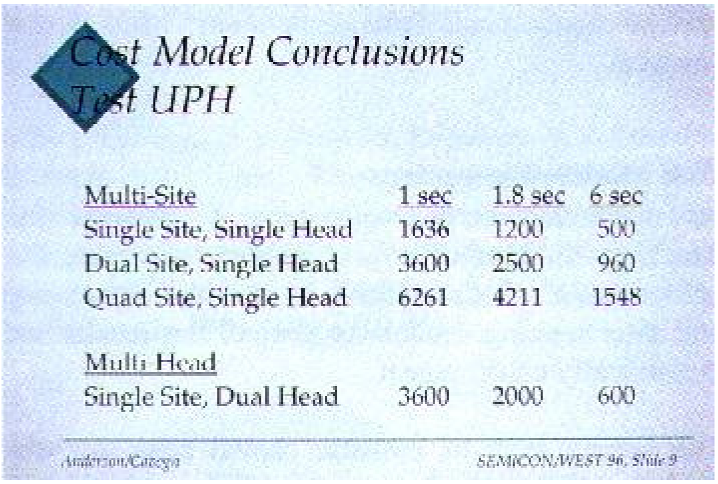
Cost Model Assumptions
As mentioned earlier, our process at NSC for attacking this kind of project involves surveying the market to see what's available to meet our objectives, and then running models to project the results we theoretically could expect.

The survey gave us realistic capital costs for our models. We kept our models simple, and did not factor in operating costs like space and power. We also got realistic index times from the survey. Although the RF portion of our test was small, we added 10% and 40% respectively to the test times for the dual and quad sites, to allow for set-up time overhead.



We compared four handler configurations: single, dual and quad site handlers on a single-head tester, and single-site handlers on a dual-head tester (SSDH). We looked at the SSDH because our target test times were close to the index times. Therefore, we figured that in a SSDH the index times could cancel out, since one site would be testing while the other was unloading and loading.

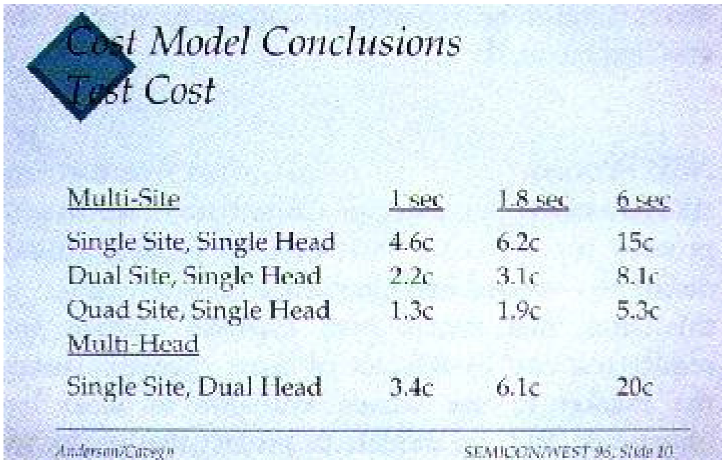
Cost Model Conclusions: Test Units/Hr.
We ran the models for test times ranging from I second to 6 seconds. The tables show selected results at 1, 1.8, and 6 seconds.

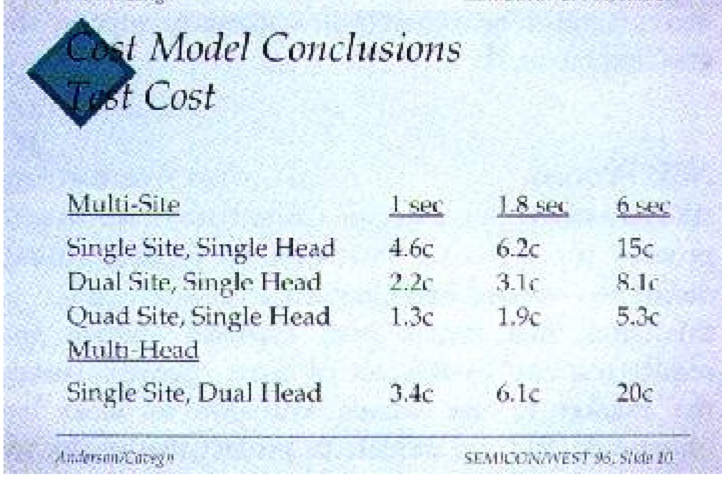


As anticipated, the units/hr (UPH) for the Single Site, Dual Head and the Dual Site, Single Head are comparable at around at I second, where the test time is close to the index time. However, the Quad Site is far superior at the target 1.8 sec test time.

Cost Model Conclusions: Test Cost

The Quad Site also turned out to have the lowest test cost. At I second, the Single Site, Dual Head is 3.4 cents compared with the 2.2 cents for the Dual Site, Single Head. The Single Site, Dual Head costs more because it carries the cost of a second handler.

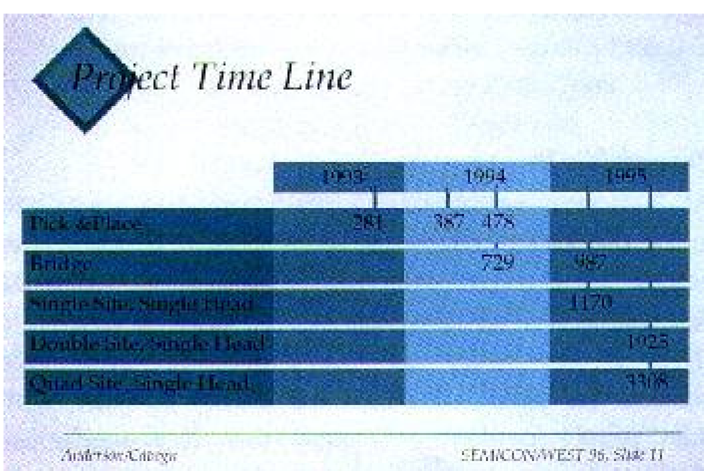




To some it may seem obvious that Quad Site is the best approach, so why bother running these spreadsheet models. We did not want to take the risk of making obvious assumptions. So at the theoretical stage, we ran the numbers, and considered all possibilities.

Project Time Line

The project time line shows the results we committed to management. The UPH figures are lower than predicted by our models, but high enough to meet our goals.



The time line also shows our strategy. It supports the growing business while minimizing risk. While we await a new handler with higher UPH, we work to improve what we already have in place. For example, we improved the UPH of the pick-and-place to 478, and then brought on the Bridge handler with a UPH of 729. "Bridge" refers to the interim, gravity-feed unit that was already available. We used it to bridge the gap between the pick-and-place and the new handler. The SSSH (Single Site, Single Head), DSSH (Dual Site, Single Head) and QSSH (Quad Site, Single Head) refer to the single, dual and quad site versions of the new handler. We wanted a basic handler design that was configurable in three versions to give us an incremental approach, where each step is the back-up for the next. We also wanted the three version feature to give us more choices for other lines at NSC.

Evaluating Suppliers
As mentioned earlier, our process at NSC for attacking this kind of project involves surveying the market to see what's available. We had clearly defined technical objectives, but there were softer, gut-feel criteria as well:

- *Have they demonstrated they can do it?*
  Questions we asked ourselves were:
    - Do they have the engineering experience?
    - Do they have the resources to apply?
    - Are they willing to do it, but haven't yet?
- *Will we feel comfortable working through the tough issues?*
  We are more comfortable when we know the company's business practices. The continuing process of building relationships is a big part of risk-avoidance.
- *Can they work with the other suppliers?*
  We looked at this project as an entire system. We wanted suppliers that could work with third parties and work through the problems for effective complimentary solutions. In the end, we selected a handler company that had already worked with the contactor company. We believe building relationships is very important.

Supplier Incentives
While we were surveying the market and selecting suppliers, we were also trying to get the suppliers as excited about the project as we were. Each supplier was going to spend its own engineering dollars, and the immediate payoff might not seem to be enough. The bigger payoffs we pointed out included:

- *NSC Business*
  There would be a need for this system at other NSC sites, and for other NSC projects.
- *Market Trends*
  There would be a demand for this system elsewhere because of the growth of the wireless market. For example, the tester supplier would rather sell more testers than retrofit an existing unit to four heads. But they had done their market research and realized the demand was there.
- *Be the Standard*
  There was the advantage of being first. For example, this project was a tough sell to the handler supplier. They would be selling only one quad machine in place of four single-

site machines. But they realized that by doing this project, they would set the standard for a quad-site, plunge-to-board system, and be the market leader.

Getting suppliers excited about the project was critical, but it took time.

Project Kick-Off
We wanted all the suppliers to work together as though this was one large system, and they were all part of the same team. We kicked off the project with face-to-face meetings. We laid out what we expected and how they would interface with the other suppliers. We went over the specifications and schedules, and gave them the purchase orders.

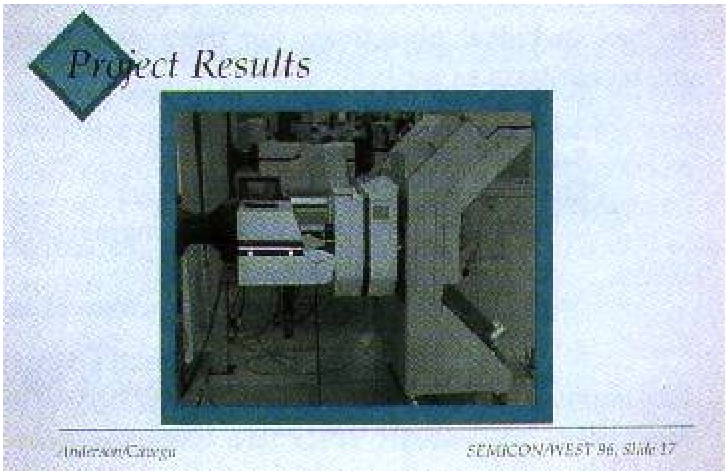
Project Management
Over the course of the project, which ran approximately 18 months, we constantly monitored events with regular meetings. We would travel to the factory and meet at trade shows. We made a big effort and spent a lot of time getting suppliers to work together as a cohesive team on one big system. We dealt with issues quickly, before they became problems. We did this in person when practical, or over the phone.

Managing Issues
Issues come up on every project. They are expected. We simply had to resolve them before they became problems. Here are four examples from this project:

- *Communications*
  We spent a lot of time trying to get the suppliers to communicate and work together. The problem is getting them together in the same place at the same time. For example, we arrived for a handler design review and was informed that there was a major problem with contactor pin-one alignment. We got out the drawings, and got the contactor people and the load board people on the phone. It turned out to be a simple misunderstanding.
- *Teamwork*
  We wanted a new 32 bit digital interface between the tester and handler, and we needed the suppliers to work together. An interesting problem arose -- neither supplier wanted to take the lead. They each said the other should define what they wanted. We finally collaborated internally and defined the interface ourselves.
- *Not Invented Here*
  The handler people began to see the contactor market as an attractive growth area. So they began proposing new contactor ideas they wanted to develop for us. This took some soul-searching discussions, about the benefits to them of partnering, and about core competencies.
- *Design Blocks*
  We had an eleventh hour crisis over DUT temperature control. The handler people were having difficulty coming up with a solution, but had indicated at design reviews they were working on it. At the last minute, just before integration, we learned they didn't have the answer. That night, at the hotel, two project team members discussed ideas, and came up with a potential solution. When we showed it to the handler people the next morning, the lights went on.

Once again, issues come up on every project. The key is to insert yourself often, persist, and resolve issues quickly.

Project Results
The project was completed two months late, but all the objectives were met. The system photo, with the tester on the left and the handler on the right, shows the cam associated with the coarse docking. The docking strategy was a key part of this system.



Project Results
At NSC, we've designed systems to dock in various ways, but in this system we chose to dock the test head/load board/contactor to the handler. We felt that was the best approach considering that:

1. The low profile contactor had a tighter deflection window than conventional, cantilevered sockets.
2. Four sites required better planarity than a single site.

We used separate gross and fine alignment. In the photo, the precision docking plate on the handler (on the right) does the gross docking with pins on the test head (not shown in this photo) and with the cams seen in the previous photo. As the system is brought together, the gross alignment starts to align left-to-right, and up-to-down. Pins on the load board, shown in the photo, provide the fine alignment in the z-axis.

Breakthroughs & Accomplishments
This summarizes the technical breakthroughs and accomplishments:

- *Increased UPH by 3.Sx*
  We increased UPH from 987, on the Bridge handler, to 3308 on the new quad-site unit.
- *Testing At 2.2 GHz, Quad Site*
  We tested at 2.2 GHz on a quad-site tester for the first time. Earlier we had achieved the 2.2 GHz, on a pick-and-place.
- *Synchronous/Asynchronous 32 Bit Interface*
  We established a new, 32-bit digital interface between the tester and the handler. It accommodates synchronous quad-site, and asynchronous capability for the future.
- *Disable On-The-Fly*
  The 32 bit interface also includes other yield-enhancing features like disabling any site on-the-fly, automatically and manually.
- *Maintain DUT Temperature*
  The system holds DUT temperature, with no time limit.

Summary
Our purpose in presenting this paper was to describe how we orchestrated suppliers. We did not attempt to describe the technical details. Rather, we tried to describe the process we used, and how it worked for us at National. Here's how we would summarize it:

- *Define Requirements & Criteria*
  Do a careful, thorough job defining what you want from your suppliers. Not just specifications, but also issues like their willingness to work with third parties.
- *Incentive & Reward*
  Spend the time getting suppliers excited about the project. Reward them when they do well. But don't be afraid to call them on a problem. Take them aside and let them know you are not happy.
- *Manage Risk*
  Build your plans with realistic data. Survey the market and learn what's available. Learn about the suppliers. Do your planning, modeling, and surveys simultaneously to test your ideas. Have back-up plans.
- *Communicate & Persist*
  Review projects often. Inject yourself and resolve issues promptly, especially between suppliers. Preach communications and the systems approach, constantly.

Acknowledgments
The authors would like to thank Lou Cartalano for his assistance in planning and writing this paper. He is an independent consultant specializing in strategic marketing and technical business writing for the semiconductor equipment industry, and is based in Los Altos, California.