

Critical Success Factors in the implementation of a Computer Integrated Manufacturing (CIM) project for CSP-BGA Packaging

Bo Soon Chang
Cypress Semiconductor
3901 N First Street
San Jose, CA 95134
USA
Email : bsc@cypress.com

Francis How
ASM Technology Singapore
2 Yishun Avenue 7
Singapore 768924
Email : francis.how@asmpt.com

Biography

Bo Soon Chang started his career at Fairchild Semiconductor Korea in 1981, where he introduced new standalone automatic die attach machine and wire bonders etc. He was relocated to Silicon Valley in 1986 to join the Fairchild Semiconductor military operations at Mt. View. In 1987 he moved to National Semiconductor as an ASIC package engineer when Fairchild merged with National Semiconductor. He joined Cypress Semiconductor in 1991, where he has installed all the new packages for Cypress Semiconductor Philippines factory between 1995-1998. In 2000 he has successfully developed and executed the fully integrated Assembly-Test-Finish line in Cypress Philippines, as factory automation program manager. Currently he is working on additional integrated lines to start production in 2001.

Francis How is a product manager with ASM Technology Singapore. He has been actively involved in motion control research and factory automation development for the past ten years. He is currently heading the Flexible Inline Systems (FIS) department responsible for strategizing, designing and developing TAP factory automation concepts and implementing computer integrated manufacturing (CIM) solutions. Francis received his B.Eng (Hon.) in Electronic Engineering from the University of Leeds in 1990 and his M.Sc. in Electrical

Engineering from the National University of Singapore in 1994. He also obtained his MBA from Nanyang Technological University, Singapore in 1999.

Abstract:

Factory automation in the Test, Assembly and Packaging (TAP) has always generated much hype and excitement amongst semiconductor equipment suppliers and chips manufacturers alike. While various factory automation concepts have been explored and implemented, the full objectives and their associated value-adding benefits that were set out to achieve remain much to be desired. We believe that a large part of the reasons for these short-falls are due to lack of concerted efforts in transferring the technological know-how between people who developed the projects and people who have to take over for the purpose of mass production.

This paper presents a detailed "after-thought" analysis of a CIM project for CSP-BGA packaging that was implemented by Cypress Semiconductor Inc, with ASM Pacific Technology serving as its major Front-of-Line (FOL) integration partner, ASA for End-of-Line (EOL) and Infinities for Manufacturing Execution System (MES) which is a software integration. It will relate the experience from both suppliers' and customers' viewpoints on how to develop a win-win partnership program to ensure that a multi-vendors project transits smoothly.

highly right from project initiation, development, through to implementation and finally its preparation efforts for total production acceptance.

Introduction

The Test, Assembly and Packaging (TAP) industry poses many exciting challenges to the semiconductor community. The working environment is highly process-intensive, with state-of-the-art technologies being researched and commercialized at increasing speeds. Clusters of scientists and engineers alike have to devote full attention to master and perfect the various IC manufacturing process steps, such as die attach, wire bonding, encapsulation and testing. Traditionally, such focused efforts have left little room or resource to be deployed for integrating the entire IC manufacturing process cycle.

It was indeed only in the last decade that management had begun to invest heavily into factory automation concepts, with reasonable conviction that their competitive advantages could be realized through the various value-enhancing benefits brought about by increasing automation activities at their shop floors.

To date, the industry has witnessed flourishing and diversified propositions to achieving the desired factory automation objectives. Typical automation attempts are by process groupings. Examples are widely varied, such as die attach through to snap cure, die attach through to wire bonds, automold through to test/finishing, etc. Automation approaches also vary from magazine-based to strip-based, with or without lots handling, lot or strip level identification, to name a few. Even leadframe and wafer designs have been modified to increase the units per strip/wafer to reduce production cycle time. Cypress Semiconductor is one such player in the TAP arena that has successfully implemented one of the industry's most advanced fully integrated assembly and test lines in their Philippines factory to manufacture matrix array molded BGA (CSP-BGA) packages. "The TRAILER" as it is referred to, has integrated the complete manufacturing processes from die attach up to tape and reel, with a cycle time of less than 24 hrs.



Figure 1 : The "Trailer"

What makes this feat, achieved in early 2000, so special is the fact that Cypress Semiconductor has been designing IC packages in the past while leaving much of the IC assembly activities to its subcontractors. Prior to this automation project, the equipment in its Philippines factory were

Project Stage	Start	Develop	Launch	Mass Produce	Follow Up
CSF 1					
CSF 2					
CSF 3					
CSF 4					
CSF 5					
CSF 6					
CSF 7					
CSF 8					
CSF 9					

Table 1 : Critical Success Factors and Associated Symbols

Symbol	Equipment	Qty	Vendor
	MES	1	Infinity Systems
	Cell Controller	1	ASM
	Die Bonder	1	ASM
CSF 1	2D Code Laser Marker	1	EO Technics
CSF 2	Snap Cure Oven	1	ASM
CSF 3	Strip-based Plasma Cleaner	2	March Instruments
CSF 4	Wire Bonder	7	ASM
CSF 5	Line Transporter	7	ASM
CSF 6	Inspection Platform	1	ASM
CSF 7	2D Code Reader	12	RVSI
CSF 8	Mold Linkage	1	ASM
CSF 9			

Table 2 : Critical success factors crucially needed at various stages of the project

In the following sections, an in-depth analysis of each of these critical success factors shall be elaborated to reveal their significance throughout the project life cycle.

Project Background

This CSP-BGA Trailer project was officially kicked off on 19 May, 1999 at the Cypress Semiconductor Headquarter in San Jose, California. The entire integration comprises 25 machines from die attach through tape and reel, spanning a total length of 120 feet. It is hooked up with two cell controllers to a higher level MES and factory planning information system. The project is essentially divided into two major modules. The Front-Of-Line (FOL) module consisted of equipment for die-attach, snap cure, plasma clean, wire bonding and post wire bond inspection, with the major equipment supplier

Table 3 : Integration equipment and partners for FOL module

being ASM Pacific Technology. Integration of the End-Of-Line (EOL) module including mold, post mold cure, solder ball placement, saw singulation, test, vision and tape-reel was managed by ASA. Details of the integrated equipment and respective vendors are listed in

Equipment	Qty	Vendor
Mold	1	ASA
Post Mold Cure	1	ASA
Ball Placement	1	Avalon
Saw	1	Disco
Sort	1	Avalon
Test Handler	1	ASA
Vision	5	ICOS
Laser Marker	1	EO Technics
Tape-Reel	1	ASA
2D Code Reader	6	RVSI
Cell Controller	1	ASA

Table 3 and 4. All equipment in each module are linked to its respective cell controller. Both the cell controllers are in turn linked to the Manufacturing Execution System (MES) to complete the CIM requirements.

Table 4 : Integration equipment and partners for EOL module

In addition to equipment suppliers, Cypress and equipment suppliers had to work closely with material suppliers to evaluate and qualify the materials to be used for the CSP-BGA packages designed. These include substrates, wafers, die-attach epoxies, gold wires and capillaries for wire-bonding process.

With each supplier taking a leading role in driving the technological partnership, close follow-up programs between Cypress and all suppliers were put in place to ensure the project progressed as planned. Five months after the kick-off meeting, all final setup and integration of the all hardware module were carried out in Singapore where both key equipment integrator are located, starting in October 1999. The entire module was ready for in-house buyoff in November, 1999.

Since the cell controller and the 2D strip marking and reading features were developed for the first time, the initial focus was on equipment process capability and materials handling procedures. The new CIM-related features were only focused upon and fully implemented in February 2000, thus allowing for appropriate priorities to be set.

As the automation concept for the FOL module was based on ASM's IDEALine strip handling approach, the risks involved in achieving the integration was relatively low. The entire FOL module was indeed successfully installed in Cypress Philippines in December 1999. By January 2000, Cypress was able to carry out qualification runs. The Trailer became fully operational in Q1 2000. By Q2, it was ramping up to 350K units per week, with a total cycle time of less than 24 hours/lot. Being a fully automated assembly line, the operator skill sets have been upgraded to handle process issues and equipment services. Hence, only 3 technical operators are

required to manage the lots running through the line instead of over 30 operators in conventional factory.

Critical Success Factor 1

Top Management Commitments

For any project to succeed, it must be blessed and totally supported by its sponsors through and through. When the sponsors uphold their visionary goals and express full commitment in words and actions, the people involved will feel truly empowered to execute the project confidently. This is especially true for projects that evokes innovative and creative technological adaptations, where risks of failure at various stages of the project are high and unpredictable. The last thing on these people's minds should be having to worry about their bosses withdrawing supports whenever a road block is on sight.

In this particular case, the top management of Cypress and ASM, ASA and Infinities shared a common vision of fulfilling the total CIM-driven IC packaging dream. So, conscencious efforts were organized to hold meetings amongst various levels to formalize ties and establish working mechanisms. At the start of the project, all top management including CEOs made a special arrangement to meet and pledge in clear, concise terms their support for this project.

Thereafter, the Vice-president for manufacturing of Cypress visited Singapore on a quarterly basis to review the project progress. Project managers and working teams collaborated weekly to monitor and manage the project jointly, both sides keeping their top management regularly updated. In addition, all supplier management also ran the extra mile to meet participating company heads to secure their commitments to this project.

Such attention and commitments from top management certainly helped foster the project team's collective wills to succeed. It also acted as a catalyst to rally the necessary support and resources from peripheral groups so as to help the project team run its course as smooth as possible.

Critical Success Factor 2

Single Integration Focus

Having the major equipment supplier provide the integration focus for the entire project is certainly helpful in developing more consistent and pragmatic solutions to the various integration related issues encountered along the way. In this project, ASM relied heavily on its past factory automation experiences and offered much consultation to Cypress, which in turn tailored these experiences to better match its internal operations and work culture.

Being the FOL module integrator, ASM was able to secure the full support from Cypress to collaborate further with the other participating companies. The advantage for Cypress as a customer was that it only had to work with ASM for FOL, ASA for EOL and Infinities for MES, on the integration-related matters. ASM would very often play host to its partners and work towards standardizing equipment interfaces and handshaking scenarios. The final "under one roof" approach to total integration helped ensure proper integration development could take place in a mutually trusted and knowledge-sharing environment.

Critical Success Factor 3

"Big Bang" Scoping

For a project of such magnitude with no previous model to emulate, it was indeed very difficult for any single party to produce a comprehensive project specification. So Cypress decided to take a revolutionary approach. Its key project managers devoted a few round trips to visit short-listed vendors and gather sufficient processing equipment information. When the top management approved the budget for this project, it held a two days kick-off meeting in San Jose, one day each for FOL and EOL modules, with the MES integrator Inifinity Systems participating in both meetings .

There were not too many people involved in the FOL and EOL module meeting. Only key technical staff from ASM, March Instruments, ASA, Infinity Systems and Cypress corporate wide cross-functional project team were involved. Together, each member contributed

his/her area of expertise and the entire session was focused on brainstorming of how the line should perform for Cypress. During the brainstorming session, many different operational "what-if" scenarios were played out. By relying on individual experiences, suitable solutions were meted out and agreed upon quickly. By the end of the meeting, most of the "what-if" questions raised in the beginning were addressed. Remaining issues that required further research works were opened as AR items to be followed up formally.

After the meeting, detailed system integration specifications were drafted by the MES integrator Infinity Systems, with revisions made based on inputs from each party. Such a practice, with the help of internet email technology, cut short the time needed to generate a custom-made operational specifications for this project. With the most significant piece of document reaching consensus early in the project, each party could move on very quickly to develop their systems to meet the preliminary specifications, at the same time providing room for fine-tuning as the project progressed.

Critical Success Factor 4

Cross-functional Advanced Party

At the early stage of this project, Cypress did a process capability analysis and decided it needed to acquire key process know-hows for this newly developed CSP-BGA package as soon as possible. Cypress identified snap cure die-attach, strip-based plasma and wire-bonding with auto vision processes, mold, solder ball placement and saw-test-finish to be very crucial towards the success of this project. Hence, "Super-users" with packaging experiences were seconded from various R&D groups to form the cross-functional advanced party. These super-users were given dedicated tasks, devoting full time to acquire specific processing equipment and materials knowledge.

Special arrangements were made to station the super-users in Singapore for an extensive period of time to carry out assembly process development and optimization. With ASM and ASA facilitating stand-alone systems, process

measurement tools and equipment process expertise, the team made a head start in optimizing and validating the equipment's capability to meet Cypress's quality specifications. Major activities included data collection with exhaustive runs of DOEs to ensure consistency and repeatability of die and wire bonding quality, verification of pre- and post-bond inspection capabilities, and auto-vision inspection correlation.

With such dedicated efforts by the advanced party, much development work on individual processes were 90% completed by the time all equipment in the FOL module became ready for the final integration. This effectively cut short the time needed to qualify the integrated module, allowing for better focus on the complete integration, which typically constitutes the final 40% of the entire project requirements.

Critical Success Factor 5

Early QA and Production Involvement

The single most important factor that distinguished this project from others was the extreme early involvement by QA and production staff. Right at the kick-off meetings of the project, QA and production management staff were already participating in the project scoping. Being the ultimate end-users of the line, they had every right to raise all their concerns about the project and express their vision on how to fulfill their operational needs.

The reason for their early involvement is to prepare these two departments for a paradigm shift in production management. People are generally not receptive to drastic changes, unless such changes can be proven to bring about significant improvements in the way things are traditionally done. Hence, helping them comprehend how to cope with new operational scenarios would have positive impacts toward final acceptance of the project implementation.

In this project, the biggest cycle time reduction could be gained from total elimination of off-line quality inspection. By fully utilizing the machine auto-vision capabilities to perform in-process QA, lots travelling through the line will not be

subject to unnecessary yield loss due to mishandling.

While the benefits of the concept sounded attractive, how could the QA personals be convinced that the machines had the capability to carry out better reject screenings than using human eyes?

To put the QA department's mind at ease, large amount of QA data had to be obtained before the line went into mass production. The exercise, called "GOOHEI" (Get-Out-of-Human-Eye-Inspection) was implemented to compare and correlate human inspection data with machine auto-vision. The data collection exercise took several weeks to complete and followed the steps as shown in figure 2. To enhance ownership and maintain data integrity, the data collection exercise was jointly carried out by Cypress and supplier's QA personals.

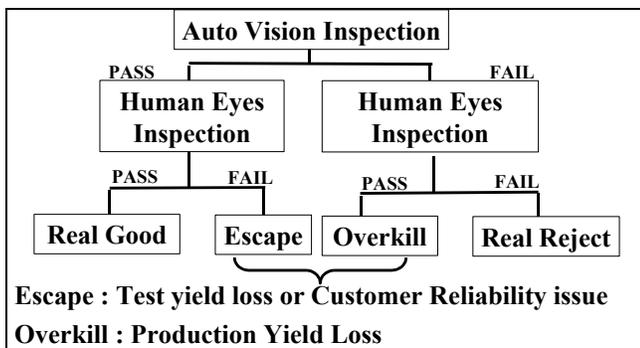


Figure 2 : Auto-Vision Inspection Correlation

Once this correlation capability studies were compiled, analyzed and shared with the operations people, it was readily embraced by them since the most tedious quality measurement tasks could be fully automated.

In addition, good technical operators were also identified early and sent to Singapore during the module integration phase. These operators worked hand-in-hand with ASM and ASA manufacturing operations people as well as the development teams from both sides to pick up the technical know-how on-the-job. The early-adoption experiences thus gained in setting up the line and equipment was invaluable to the operators during production runs as they would feel less dependent on service engineers and

technically more competent to manage the entire line operation.

Critical Success Factor 6

Technical-driven Problems Solving Approach

Many a times, whenever a problem surfaces in the middle of a project, the spot light is shoned on who or what caused it rather than how to overcome it. Since the working team was primarily motivated by the technologically challenging nature of this project, the mindset in solving problems along the way was based on "let's find alternative methods to make it work", not "never done it before, so should not work". This ultra-positive "never say die" attitude was established early in the game by respective project leaders, with a common goal of developing the world's first fully CIM-based CSP-BGA assembly line.

One good example of such technical-driven approach to solving a problem was the frequent occurrence of second bond non-stick detection false alarm which happened during the adoption of the new snap cure epoxy formulated by the epoxy vendor. Instead of solely attributing the problem to the wire bonder's non-stick detection mechanism, all possible causes to this non-stick problem were thoroughly examined. No effort was spared in studying the lead-ins to the problem, ranging from substrate pads grounding connectivity, epoxy silver flakes mixing contents, right down to wire bonder's detection software algorithms.

The fact-finding exercise led to a few days of systematic testing, measuring and validating activities. Eventually, the root cause of this problem was found to be inter-linked. With the delicate relationships of these causes clearly established, it became relatively easy to get respective parties to introduce appropriate changes to their designs to resolve the issue once and for all.

Hence, when working on a technical project, investing in worthwhile efforts to manage a crucial multiple-facets problem and clearly define their inter-relationships will certainly allow participating groups to reach a consensus to the

eventual solution, which tends to nip the problem in the bud. Conversely, problems which do not get properly pinpointed tend to be at best, resolved for a while using a patchy solution, only to have it surface again during mass production stage, right when one could ill afford it.

Critical Success Factor 7 Develop Team Ownership

One very important success factor in a development project is to inculcate genuine team bonding spirits. Both user and all suppliers had placed strong emphasis on team ownership by linking the key technical members from both companies together through specific task delegation. methods

The project leaders would hold regular meetings, either through teleconferences or face-to-face, to draft out the critical milestones and objectives to be met. Members of the team would provide inputs as to when and how these milestones could be achieved. With a transparent project management approach, all members of the working teams would feel duly respected for his or her technical contribution. They also became more pragmatic and are willing to put aside their pride to request for each others' help when resolving difficult technical issues.

Developing team ownership also means the job responsibilities must be structured such that there is no room for individuals to ask "What's in it for me?". Every technical challenge encountered in the project has to be dealt with using the "When it gets resolved, system will work better, and life for everyone will improve!". Hence, during team discussions, members would be more responsive and eager to contribute their knowledge and effort towards fulfilling or even exceeding the project expectations.

Critical Success Factor 8 Team-based Performance Measurement

The building of team ownership has to be supplemented by a team-based performance measurement system. On a regular basis, project update meetings were held with senior

management involvement. The cross-functional teams would have to present their progress and findings together. Key technical issues or major stumbling blocks were raised during such meetings to highlight how the senior management could step in to help overcome.

In FOL's case, the senior management in ASM would play an active role in realigning company resources and priorities so that appropriate efforts could be channeled in to push the project forward. In Cypress's case, the cross-functional team members would put forward their overall progress status to their senior management, highlighting their achievements and pitfalls to date.

Senior management would measure these collective outputs and devote efforts to assess their performance as a team. When a project objective failed to be achieved as planned, the team was expected to provide a good explanation. There was no incentive to give answers like "He caused it!" or "She did not do it!". Every effort was focused around "Where is the problem?" and "How can we resolve it?". The sense of urgency was well exhibited by all parties and it translated into positive synergy among the team members.

The risk of such a team measurement approach is to have the team collaborating together to cover up each others' shortcomings. However, this should be tolerated to a certain extent since the final deliverables are the ones that really counted. So, giving the team some room to give and take in their own capacity does better serve the long term objective of team building.

Critical Success Factor 9 Appreciation and Recognition

By the end of Q2 2000, when the CSP-BGA Trailer had churned out 1.27 million parts and exceeding Q2 production target, the team members involving in this development were overjoyed to see their months of collaboration finally bore fruits.

Cypress senior management was quick to show their appreciation for this successful implementation and took tangible steps to

recognize the team's efforts. They organized a project appreciation ceremony at the Philippines plant, inviting all participating vendors to grace the celebration. Appreciation plaques were presented by Cypress top management to all the vendors' management representatives. This heart-warming gesture, though short and simple, struck a note close to the hearts of all participants. Good business partnerships were made, and more importantly, friendships were forged during the project, laying the foundation for continuing partnership on more challenging projects in the future. The Cypress corporate wide cross-functional team members were also recognized for their hard work and precious contributions. This simple reception helped to disseminate a very strong message to everyone present, that the Cypress management is very serious with its vision to drive for total Computer Integrated Manufacturing concept and would like to encourage their staff to maintain this innovation excellence spirit.

With this official appreciation and recognition strategy, it helps cement the company's resolve to repeat its success in future implementation of Trailer projects for new IC packages.

Conclusion

This paper presented an in-depth analysis of the critical success factors contributing to the successful transition of a totally new CIM CSP-BGA Trailer project for mass production. They are summarized as follows :-

1. Top management commitment
2. Single Integration Focus
3. 'Big Bang' scoping
4. Cross-functional advanced party

Acknowledgments:

Bo Soon Chang, Cypress project manager for The TRAILER, would like to acknowledge the Cypress project team and management in Philippines, and San Jose for their contribution and support to this project. Cypress would also like to thank all their equipment and material suppliers, with special thanks to ASM Technology-Singapore, Advanced Systems Automation-Singapore, Infinity System-USA, ICOS Vision Systems-Belgium, EO Technics-Korea, March Instruments-USA, Agilent Technologies-USA, Disco Hi Tec-Japan, Shinko Electric-Japan and all other parties for helping make "The TRAILER" successful.

5. Early QA and production involvement
6. Technical-driven problem solving approach
7. Develop team ownership
8. Team-based performance measurement
9. Appreciation and recognition

While these critical success factors are mainly strategies-related and required tactical deployments, they do not overshadow the pre-requisites for a good technical project implementation. The foundation of such projects shall be based on thorough selection of processing equipment vendors, careful risk management of new technological adaptations as well as a clear management mandate to achieve competitive advantage through factory automation.

References:

1. Vani Verma, Bo Chang, "THE TRAILER : A Fully Integrated Assembly-Test-Finish Line for Matrix Array Molder BGA", Semicon Show Korea, 2001
2. KT Yeo, "Strategy for risk management through problem framing in technology acquisition", International Journal of Project Management Vol.13, No. 4, pp. 219-224, 1995
3. Jack K. Lemley, "Human factors in the management of the channel tunnel project", First International Conference on Construction Project Management, January 1995 (Singapore)
4. J. Pedro, L Estacio, "Using Electronic Strip Mapping for Tracking Defects in a Fully Integrated Assembly and Test Line", Semicon Show Singapore, 2000