WHITEPAPER

LEAN NPI AT OPTIMUM DESIGN ASSOCIATES: PART 3 BEFORE AND AFTER

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This paper is the third in a series that describes, as it progresses, the journey of Optimum Design Associates (Optimum) from initial concept and planning through our implementation of Lean NPI. This third paper examines data from before implementation and compares it to the data that has been compiled over more than a year of using Lean NPI as a best practice.

Optimum is an EMS company that provides design & layout services along with full turnkey PCBA manufacturing. Having all of this in-house gives our design team a unique perspective and understanding of both the electronic and manufacturing requirements to implement a successful design.

If you have not yet read the first two installments, those provide background applicable to this paper and downloading them is recommended. In the first paper (***Lean NPI at Optimum Design Associates: Where are we now?***), the then-current business practices at Optimum were described, including the design flow and integration of Mentor Graphics layout tools and Mentor Graphics Valor NPI design for manufacturability (DFM) tools. It also describes the process to set up and launch our Lean NPI program.

The second paper (***Lean NPI at Optimum Design Associates: What is NPI and How to Achieve it***) describes why and where processes can be implemented to align Optimum with the best practice Lean NPI model, which was the product of collaboration between Optimum and Mentor. It also introduces metrics that allow the progress to be tracked and measured.

LEAN NPI MODEL

First, a quick refresh on what exactly the best practices Lean NPI model is that Optimum has defined, Illustrated in figure 1. In the Optimum model, there are three critical elements to the Lean NPI model.

The first integral part of Optimum's model is using an intelligent manufacturing data transfer method. Our preferred method is to use ODB++ for every customer we can. Using ODB++ allows quick importing of all necessary manufacturing data from the PCB CAD software to the CAM tools.

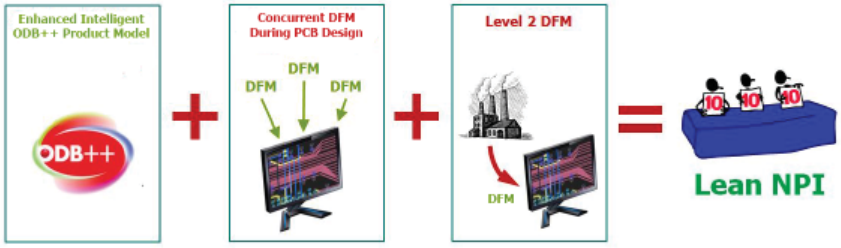

Figure 1: The three keys to Optimum's Lean NPI model.

The next important element is concurrent DFM during PCB design. This means that incremental DFM checks can be run at various layout milestones, such as placement approval, critical routing, full copper connectivity, and final approval.

Third, perform Level 2 DFM as defined in the previous papers. This means adding specific vendor rules into the DFM rule set. This assures that the board fabricator's rules are followed.

PROGRAM GOALS

Being an ISO certified supplier, we made Lean NPI a Continuous Process Improvement (CPI) initiative. Representatives from our manufacturing, layout, and the quality team set the goals we wanted to achieve. As with any CPI, the overall goal is to improve yield and reliability in the most efficient manner possible.

Lean NPI program goals:

1. Streamline the process of preparing and delivering intelligent manufacturing data files. Before ODB++ adoption, Optimum assembled more than 30 separate files in a manufacturing package. Using just one intelligent ODB++ file, significantly reduces the deliverable output time as well as reduces setup time throughout the manufacturing chain.
2. Find DFM issues in layout as close to real time as possible. Performing DFM throughout the process to "left shift" in time to solve potential issues early on, saving time and money.
3. Fine tune the DFM rules (ERF files) to match as closely to both Optimum's and our vendors' capabilities. Failing to consistently modify the rules to match manufacturing capabilities provides an inaccurate picture.
4. Define a set of metrics to track and measure continuous quality improvement. The goal is not necessarily to see numbers trending down, but to call the designer's and customer's attention to the potential issues that can affect yield and reliability of the PCBs.

THE LEAN NPI PROCESS

The Lean NPI process is shown graphically in figure 2. This shows the entire process from concept through manufacturing handoff.

The first step is to validate the Bill of Materials (BOM) using Mentor Graphics Valor NPI and Valor Parts Library (VPL). This ensures that all the part-numbers, reference designators and quantities are correct and that VPL package models are available for later use in the design flow. Next the components are placed and a DFA is run. Results from the DFA are incorporated into the design and the rest of the design is then completed.

After our customer has reviewed and approved the design, a full DFM analysis is run and results reported to our designer. Any issues are fixed in the design and DFM checks are run again until clean. A final package is then released to be manufactured.

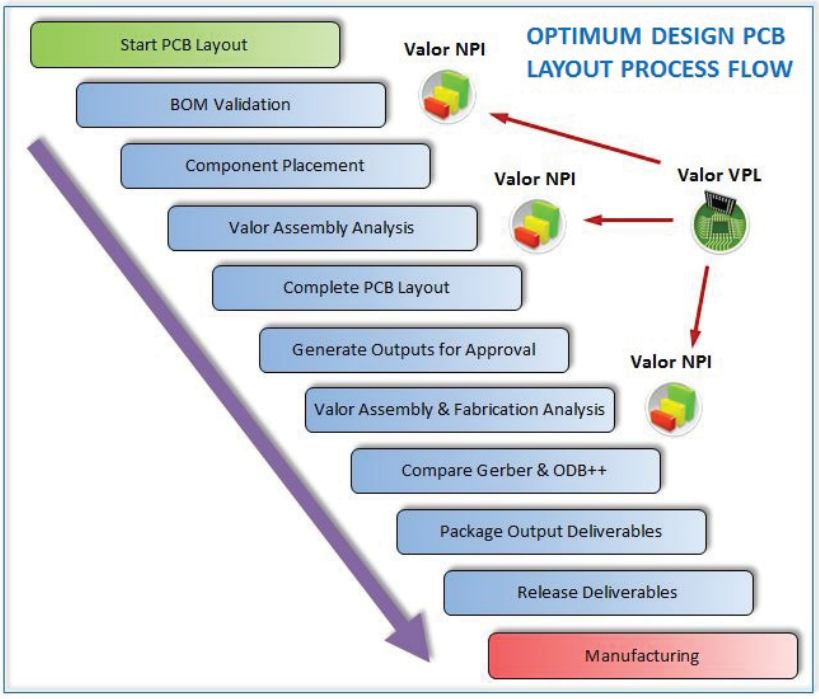

Figure 2: Optimum's complete flow for PCB design.

ODB++

The ODB++ intelligent manufacturing data transfer method is important to the implementation of Lean NPI at Optimum. Since concurrent DFM involves moving DFM to as early in the project as possible, it is essential to perform the DFM checks as quickly as possible to maintain very tight schedules. Valor NPI tools perform DFM efficiently at all stages of the design. Using ODB++ frees up time that was previously used to set up the myriad of files for these DFM steps too. Figure 3 illustrates all the files required using Gerber and the adjunct files also required, as compared to a single ODB++ file.

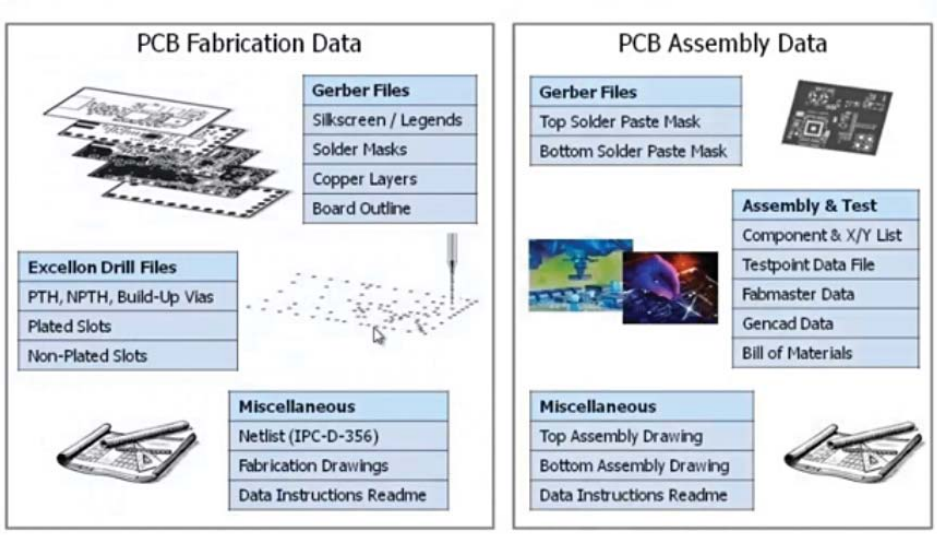

Figure 3: Gerber-type data requires more than thirty files to contain all manufacturing data.

The ODB++ file itself is really another CAD database that is made up of all the necessary files, organized into folders and compressed into a single .tgz file…everything the manufacturer needs in just one file. Figure 4 shows the structure.

As mentioned earlier, before embarking totally on a plan dependent on ODB++, we needed to be confident that it truly had all the data embedded into the one file to manufacture a PCB. So, for about six months, we added a step into our standard process where it checked the ODB++ file against the Gerber data to ensure it indeed had all the necessary manufacturing data. We did this using the Gerber Compare feature in Valor NPI. Over the course of about six months and a little over 100 design deliverables, we found confidence to move completely over to ODB++ for all future designs.

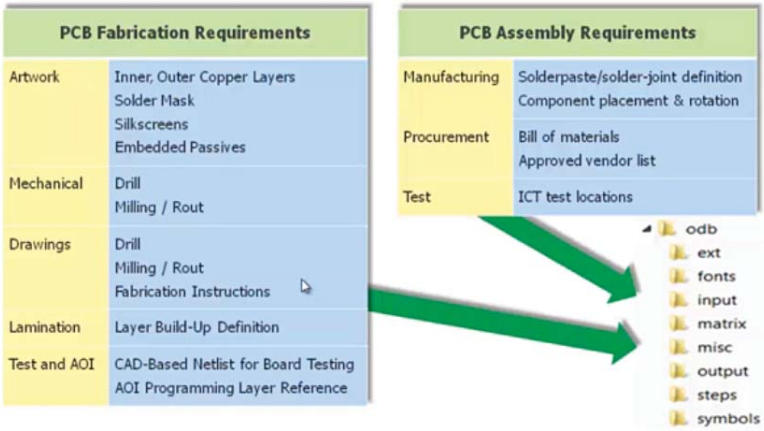

Figure 4: The single ODB++ file is a CAD database that comprises a compressed set of the entire manufacturing data set.

LEFT SHIFT DFM

The second goal was to move DFM earlier in the process. When DFM was left shifted to earlier in the process, we were able add two new fabrication analysis steps. The first is after critical nets have been routed. This finds any problems with those important nets as early as possible, providing the opportunity to rectify them quickly and inexpensively. The second added check is when we have full copper connectivity. Now, knowing that the critical nets are manufacturable, the DFM step checks for errors in the balance of the design, and of course checks to see that nothing has been "broken" with the rest of the layout. With the Valor tools, running DFM is fast and easy. Speed is the key to be able to do this (both speed of setting up ODB++ and also running the checks).

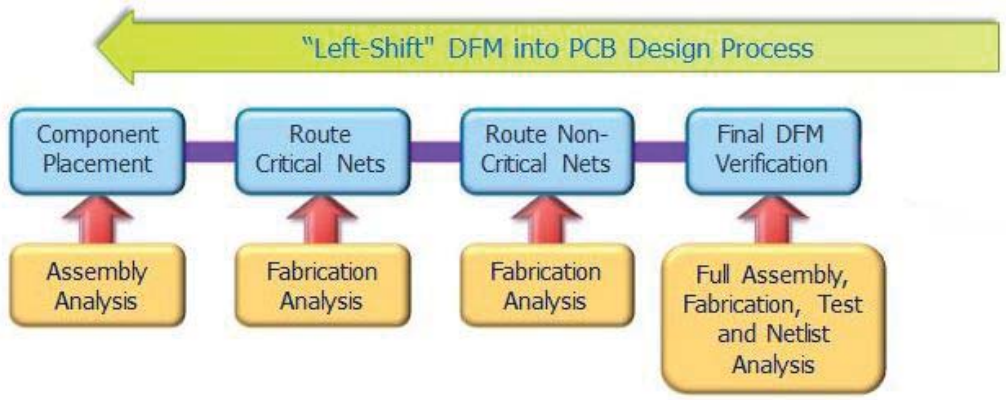

Figure 5: Shifting DFM to earlier in the project allows manufacturability checks to be run concurrently with the design itself.

FINE TUNE THE RULES AS YOU GO

This brings up the third goal: fine tuning the rules. The Valor tool comes with almost 900 rules (ERF's) out-of-the-box and for the most part are pretty good, however, as a contract manufacturer, Optimum felt it needed to fine tune these rules to better match our own internal processes. In the case of fabrication checks (DFF), our approved suppliers provide and allow us to use the same ERF's that they use internally.

On occasions where we design a PCB and don't necessarily know which vendor will be fabricating the board, we have a set of rules that best match all vendors' requirements. Our rule files are then reviewed quarterly by our team representing layout, manufacturing, and quality based on Valor NPI and assembly post mortem reports. This allows them to continually update our rules to eliminate any errors we find in order to improve yield and reliability as well as reduce the number of flagged checks during DFM.

MEASURE AND COMPARE

Data has been collected throughout the implementation of the Lean NPI process. The goal is to improve quality, reduce errors, and identify areas for improvement. By observing the violations found during the DFM checks performed at Optimum we can identify common issues trends. We can then educate our designer's and find ways to mitigate the problems in our designs before we ever get to manufacturing. For example, the use of soldermask-defined-pads has become more popular and important to the success of a design as features continue to shrink. Our layout designers are continually improving their skills as we receive a steady stream of DFM feedback with each new design we complete. The rest of this paper presents the data collected and its interpretation.

COLLECTED METRICS

The goal with Lean NPI is to eliminate projects from going on hold and to improve the yield of each board released to manufacturing. Since the fourth quarter of 2012, when Lean NPI was implemented at Optimum, statistics have been compiled. Those statistics tabulate the design errors by type and severity. The most severe in Optimum's judgement are callbacks; that is, when the supplier stops a project because of an error that would compromise yield and/or quality.

Looking at the callback history we can see a downward trend of vendor callbacks that would inhibit the progress of the project. Virtually all show-stopper issues have been eliminated and only an occasional review of less critical items such as suggested stackup modifications, fab note conflicts, or other minor topics that we are asked to review. As Optimum has gained experience with DFM, the number of all callbacks has been reduced to less than one per quarter, and those were "suggestive" issues: items that did not require artwork change. At the same time that callbacks were being reduced, the number of designs has been gradually increasing.

In 2014 Optimum Design started offering Valor DFM checks as a service to our customers and also began a very

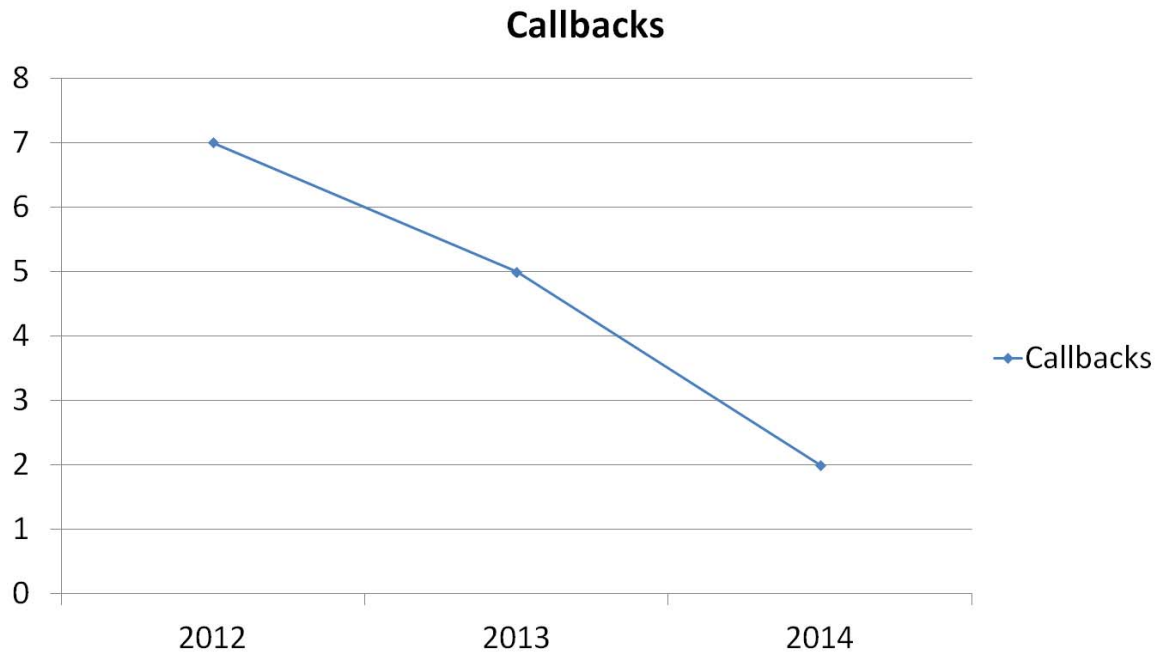

Figure 6: Since introducing Lean NPI in the fourth quarter of 2012, the number of callbacks has steadily decreased, and no "show stoppers" have been logged in 2013 or 2014.

pro-active role in running DFM checks on all new incoming assembly projects (not just PCB layout projects). These designs undergoing DFM checks have been created by outside companies and may not have followed Optimum's preferred layout practices. These additional designs have greatly increased the number of DFM checks performed quarterly and the number of violations found. As seen in previous years, Optimum's mature layout process and experience gained from DFM feedback has resulted in fewer violations found.

The most revealing statistic in the data that has been compiled is the number of defects discovered per report. This number normalizes the data to eliminate the skews due to the increased number of projects checked. Again, the most important errors are the ones that cause the project to halt — the "show stoppers." The table below shows the number of design reports per year, and the number of defects, plus the ratio of defects/report.

	2012			2013			2014		
	Defects	Reports	Defects/ report	Defects	Reports	Defects/ report	Defects	Reports	Defects/ report
Critical Issues	213	58	**3.672**	345	135	**2.555**	264	155	**1.703**

The graph in Figure 7 clearly shows that the expertise that Optimum has acquired is paying off extremely well. The number of "Critical" class errors decreased from 3.67 per report in the fourth quarter of 2012 to just 1.70 per report in 2014. This indicates that as Optimum's experience with Lean NPI grows, the designers ensure major problems are avoided during the design itself.

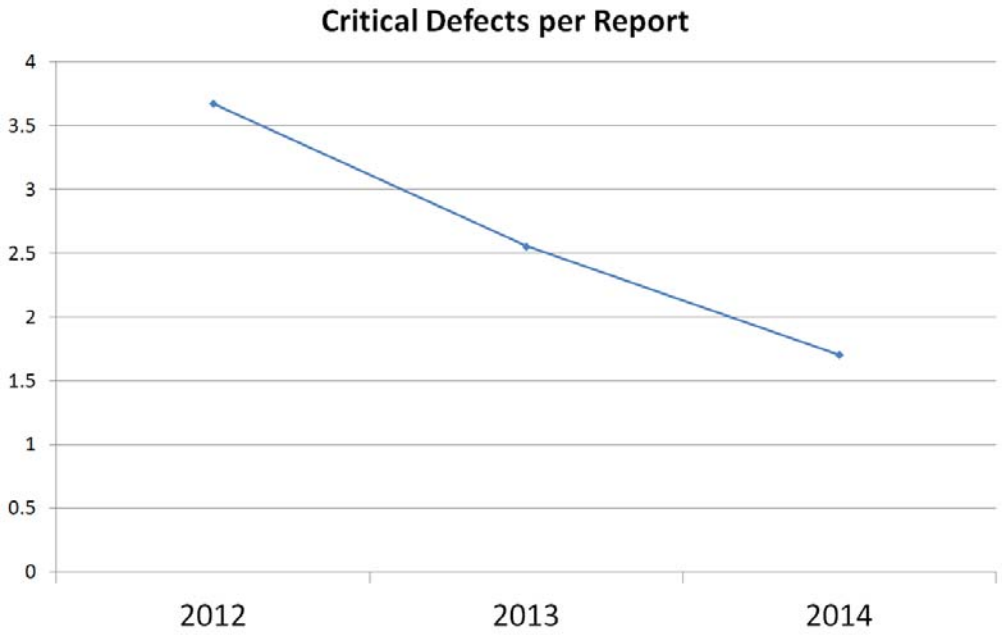

Figure 7: The number of critical defects (show stoppers) per report shows a reduction of more than 50% in just over two years.

Another indicator that validates the ongoing Lean NPI investment is the amount of time that is spent on each project, readying it for production. Before Lean NPI, most of the data files submitted to Optimum used Gerber PCB data and supplementary files with manufacturing data. Part of the implementation process was to move as many designs as possible to the more intelligent ODB++ format, which packages the complete set of manufacturing data as well as the PCB design data.

The table below summarizes the significant improvements recorded during the last two-plus years.

Operation	With Gerber Data	With ODB++ Data
DFF	2-5 hours	1-2 hours
DFA	Not feasible; could take days	4-6 hours
CAD Output	10-20 minutes	1 minute

ONGOING PLANS

Optimum has implemented Lean NPI and has now been using the model for more than two years. At this point, we have great confidence in ODB++ but we still have to offer Gerber to a few customers who have not changed over. The supporting data shown on the previous page indicates that despite undertaking more DFF checks for customers, we have been able to continue decreasing the number of critical defects. And, it is taking much less time to deliver higher quality designs.

Left shifting DFM is catching errors much sooner in the project than ever before, allowing them to be quickly and inexpensively rectified. Additionally, the review and updating of rules files have also shown positive benefits. Still remaining is to educate those customers who still depend on Gerber data and work toward complete ODB++ usage. Implementing Lean NPI has helped ODA achieve the goals of high quality, high reliability and at the lowest cost possible.