

# Development to High-Volume Manufacturing: Reducing the Risks

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The economic effect of a yield crash on a new product launch can be devastating, so anything we can do to reduce the risk entailed in transferring a process from development to high-volume manufacturing is effort well spent. Manufacturers have learned important lessons in risk reduction from years of experience with a ubiquitous tool: failure modes and effects analysis (FMEA). FMEA helps us to identify what could go wrong, to quantify the effects of things going wrong and to assess the overall risk due to each possible failure mode. However, FMEA as typically practiced may not be sufficient to assure a smooth transition from development through the product ramp to high-volume manufacturing. We describe statistical methods that can be used to turbo-charge FMEA technology and assure a much more productive start-up.

An absolutely critical aspect of the FMEA procedure is the discovery or reasonable anticipation of a comprehensive set of failure modes: if you don't know what could go wrong, there is nothing you can do to keep it from happening or reduce its impact on the process. FMEA practitioners try to anticipate or imagine possible failure modes but their efforts can be improved through the use of screening designs. These highly efficient experiments enable the investigator to explore many possible influences on process outcomes with a minimum of experimental runs; some designs (supersaturated) can even investigate many more factors than there are runs in the experiment. Historical data analysis techniques are somewhat less trustworthy because of possible confounding with unrecorded process variables, but if a large volume of data is available multiple linear regression and discriminant analysis are likely to discover some previously unsuspected failure modes.

Once failure modes and their effects have been determined they are evaluated on three scales: severity, occurrence and detection. The most damaging failure modes are those that have a severe adverse effect on the process, occur relatively often and are difficult to detect. As part of an overall risk management plan, FMEA can be used to recognize undesired events before they cause much damage (reduce the detection index), to reduce the frequency of unwanted failures (reduce the occurrence index), and perhaps even to make the process more robust (reduce the severity index) so it can better tolerate some failure modes.

Robust design techniques are effective in reducing the severity index. These are well-established DOE (design of experiments) methods that can lead the process designer to select control variable settings that are relatively immune to the effects of noise variables that vary uncontrollably during manufacturing. These experiments are necessary early in the development process because the development environment may not otherwise experience the effects of some noise variables due to the relatively small equipment set and higher level of control typical in a development environment, but unlikely in high-volume manufacturing.

The occurrence index can be reduced by finding root causes for failure modes and then eliminating or reducing the incidence of them. Screening designs and other DOE techniques can help to discover and verify suspected root causes, and they are also effective in evaluating process changes. In cases where no logical suspected causes are apparent but a substantial history on similar prior processes is available, multivariate investigative techniques such as stepwise discriminant analysis can bring likely suspects to light.

Statistical process control is essential to failure mode detection and modern techniques like multivariate SPC significantly enhance detection ability. Some aspects of a process should remain the same regardless of process scale: variance components in a diffusion process or spatial patterns in a single-wafer etch process, for example. Statistical monitoring of these outputs can detect known failure modes as well as discovering novel failure modes unique to high volumes.

Transition from development to manufacturing is not only just a transition from low-volume to high-volume, but from the development environment to a manufacturing environment. Differences in equipment multiplicity, tool utilization, informal monitoring practices, maintenance procedures and personnel can all translate to scale-up risk. We can employ FMEA with a comprehensive set of statistical tools to anticipate some of these risks and mitigate them before they cause unnecessary economic losses.