Evaluating the Fab Lifecycle and SubFab service maturity model:

Is there more to gain?

Semiconductor manufacturers appreciate that maximizing fab profits requires high subfab functionality. Nevertheless, many plant managers view subfab maintenance as an unavoidable cost rather than an opportunity to lower overall expenses while increasing uptime. The experts at Edwards Vacuum delve into this dilemma, sharing insights for achieving balanced, optimized outcomes.

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THE VACUUM and abatement systems that support semiconductor manufacturing processes in the fab are critical – if they are down, so too are the process tools they support. By the very nature of their function – to remove and render harmless process exhaust while maintaining the vacuum conditions required for the process to operate – they are exposed to harsh process chemicals and by-products that make regular service or replacement unavoidable.

Even more costly than planned maintenance is unexpected failure, which can impose additional costs for product losses and repairs to process equipment. Improving the management of vacuum and abatement systems offers significant productivity gains by minimizing both planned and unplanned downtime.

Smart Manufacturing tools and Industrie 4.0 principles are becoming more accessible to manufacturers, where data-driven optimization of maintenance scheduling, namely predictive and proactive approaches, offer the benefit of minimizing downtime and risk of failures. For these approaches to achieve the desired results, differing levels of collaboration and domain expertise are required. The service maturity model helps to visualize progress towards this goal as movement up a maturity hierarchy. This progress must be considered in the context of the fab lifecycle, and, at a more granular level, individual product and process lifecycles. The service strategy must be agile enough to accommodate shifting priorities throughout lifecycles. A critical ingredient, and often the most significant contributor to successfully implementing a smarter approach, is the level of collaboration needed to enable the free flow of critical data. At the highest level, maintenance is transformed from a support cost to be minimized to a value-adding investment that increases productivity.

Service Maturity Model

The mechanization of manufacturing, using machines to multiply the productivity of humans, was the basis of the first industrial revolution – Industrie 1.0 if you will. Ever since, as the role of machines has grown and evolved, and now as the industry embraces Industrie 4.0 and Smart Manufacturing, the methods and approaches to supporting and maintaining those machines have also evolved. The service maturity model (figure 1) classifies approaches to service in a hierarchy of five levels and visualizes the evolution as progression up the hierarchy. The lowest level is to do nothing – worry about it later. The next is reactive maintenance – run-to-fail and fix it when it breaks. At this level, maintenance costs are viewed as a non-

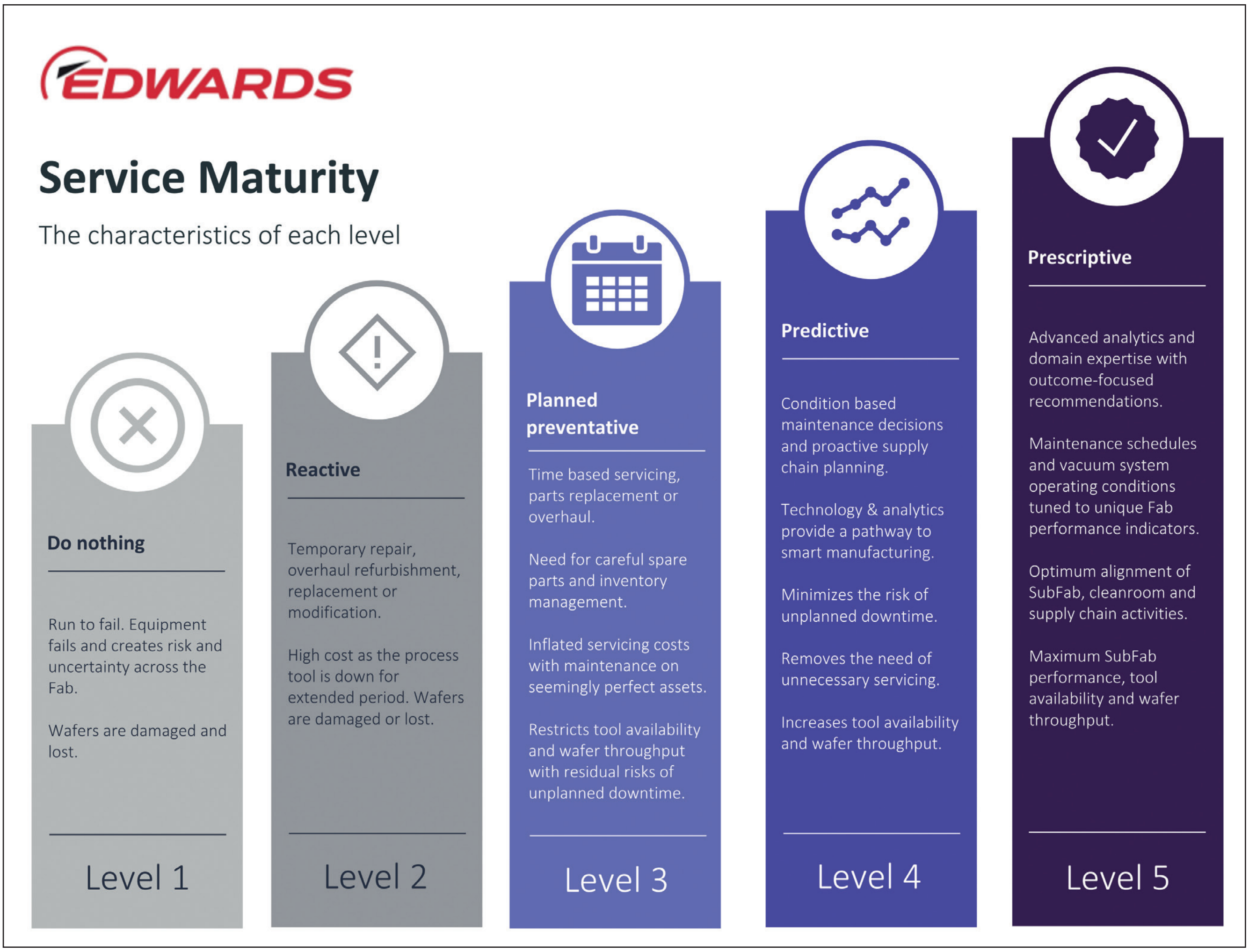


Figure 1. A service maturity model defines a hierarchy of services philosophies.

productive expense and the focus is on minimizing that cost. The next level up is planned/preventive maintenance. Here manufacturers begin looking at the value added by maintenance through improvements in efficiency and performance.

Maintenance is scheduled periodically to occur before the equipment is likely to fail. Essential components of this approach are determining the optimal service interval, standardizing performance and procedures, and finding opportunities for improvement. Predictive maintenance, the next level, is condition-based and relies on increased monitoring of operational parameters to predict imminent failures. It seeks to maximize the time between interventions while avoiding unplanned failures. The highest level in the progression is prescriptive, in which close collaboration between the user and the provider and a shared commitment to continuous improvement promotes a prescriptive approach to maintenance with adjustments to machine operation that optimize outcomes to achieve the user's goals.

The progression described in the service maturity model allows service providers and consumers to understand their position in the hierarchy and align their programs to achieve desired outcomes. Service is not a one-size-fits-all proposition. Different customers and providers will find themselves at different levels. Indeed, the same customer may be at different levels in different parts of an overall manufacturing operation. For example, some Edwards on-chamber vacuum solutions run under a predictive model while many SubFab solutions are still managed with a run-to-fail approach. The service maturity model is most useful as a framework for determining the best next step in the continuous effort to improve user outcomes.

Challenges

The greatest challenges posed by the maturity progression are related to the increasing collaboration required at each level. Every higher level requires greater understanding of the user's environment and process. At each level, the solutions must be more customized to reflect differences in processes. Each level requires more information to flow in both directions to characterize the state of the equipment, then assess and apply the required domain knowledge to enable continuous improvement. The barriers are not always technical; for instance,

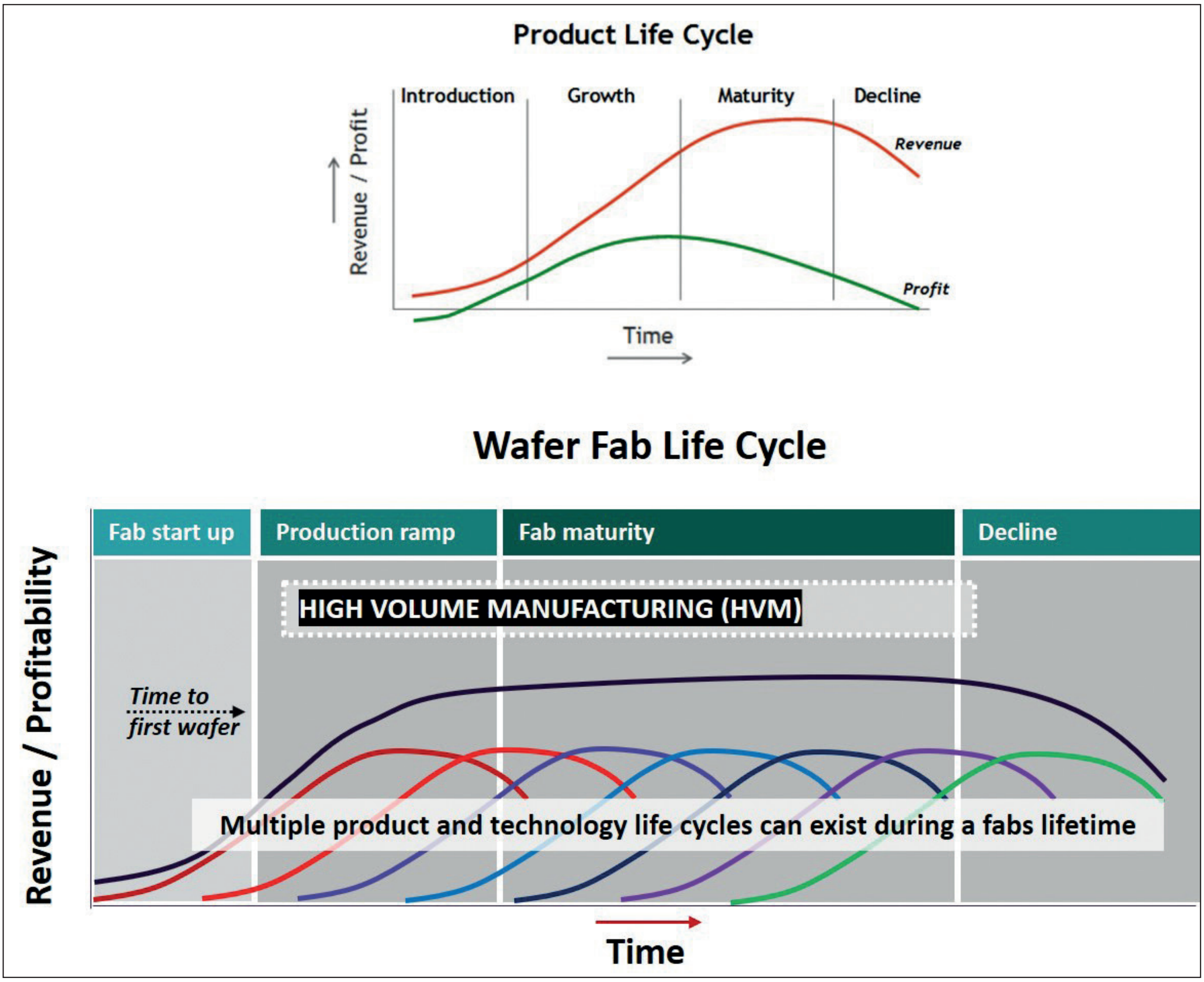


Figure 2. Service requirements change as fabs go through a lifecycle.

they may be driven by organizational concerns about confidentiality and data security. Each level requires a broader view of the operational context and an increased understanding of other equipment and environmental variables that may affect performance and efficiency.

Some of these needs can be addressed by technical innovation in the design of the equipment, such as adding sensors to monitor relevant performance parameters or cloud storage of data to offer faster access to a larger data set. Others are cultural, such as overcoming historic industry biases against data sharing and suspicions about cloud storage security. Some technical innovations are still in the early stages of their own evolution. Machine learning, in which machines analyze their own performance and self-correct, is only beginning to take hold. Artificial intelligence may someday rival human intelligence in its ability to solve complex problems and implement goal-oriented solutions, but it is not there yet. These and other advanced technologies are still at a point where their recommendations require human review. Even the most mature service approaches still rely on the creativity of humans for innovative solutions. At a minimum, these advanced technologies offer significant value by reducing the amount of data review, alerting operators of suspect conditions. They are tireless monitors that never need to eat or sleep.

Fab Lifecycle

A wafer fab life cycle (figure 2) is very much like the life cycle of the silicon chips the fab produces. Productivity and profitability follow a familiar curve from slow start through accelerating growth, peak performance and eventual decline.

- **Start-up –** The initial stage includes building the fab, installing the first equipment, and recruiting and training the staff required to run and maintain the equipment and processes. All focus is on producing “first silicon”, those all-important initial yielding wafers. Any delay is costly and service expenditures are minor relative to the overall investment at risk.
- **Ramp –** The growth stage in a wafer fab, the “production ramp”, is all about improving capacity, yield, and economies of scale to reduce costs and increase income.

- **Mature –** The focus is on maximizing profit. Here the fab life cycle differs from the product life cycle as new products and technologies can be introduced to extend the fab's life expectancy.
- **Decline –** Even with the constant upgrades of equipment and process there comes a time when a fab becomes unprofitable. This stage may be greatly extended by transitioning to products that do not require advanced technologies.

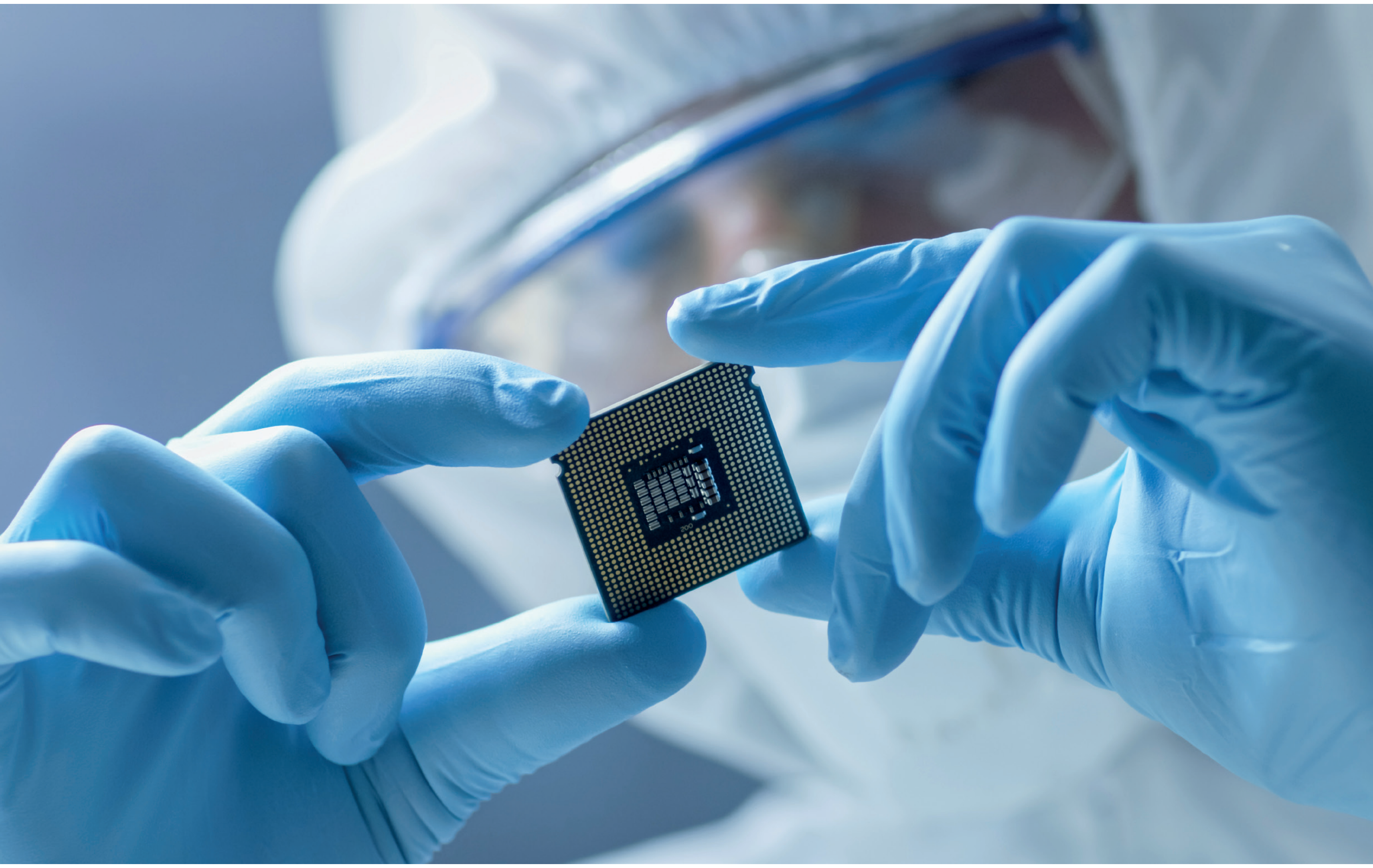
During each phase of the fab's life cycle different priorities drive the need for different skill sets and maintenance approaches.

Start-up is about project management: delivering, installing, commissioning, and setting up the equipment in a fast and effective manner. Most of these activities are carried out by the equipment manufacturers. Maintenance is lower down the food chain as the equipment is new and should perform. Preventive maintenance is likely to be the best approach during this phase. This is when equipment manufacturers need to study performance data, apply and modify domain knowledge, and determine a base-line performance for maintenance scheduling, while their customers focus on first silicon, staffing, and training.

The ramp phase can be especially challenging - it is critically important to avoid any surprises. A preventative approach may deliver best results as more equipment is coming online and first silicon is out the door. Pressure is intense to ramp volume and minimize any negative impact of maintenance. This requires skill sets and resources that are different from initial equipment installation. Growing pains are common as head counts grow for both user and service provider.

Providers must focus on how their equipment is behaving, optimizing maintenance schedules, refining parts inventories, and applying standard work practices. The user's focus now shifts to increasing output, uptime, and yield, while they continue to grow the workforce in numbers and experience. Installs and maintenance are in most cases still performed by equipment manufacturers, but a transition begins as users start to take more ownership of maintenance activities.

A mature fab never really stands still as products and technology continually change and there is pressure to maximise output. New equipment and processes are introduced, which can change the way support equipment reacts. Equipment manufacturers must



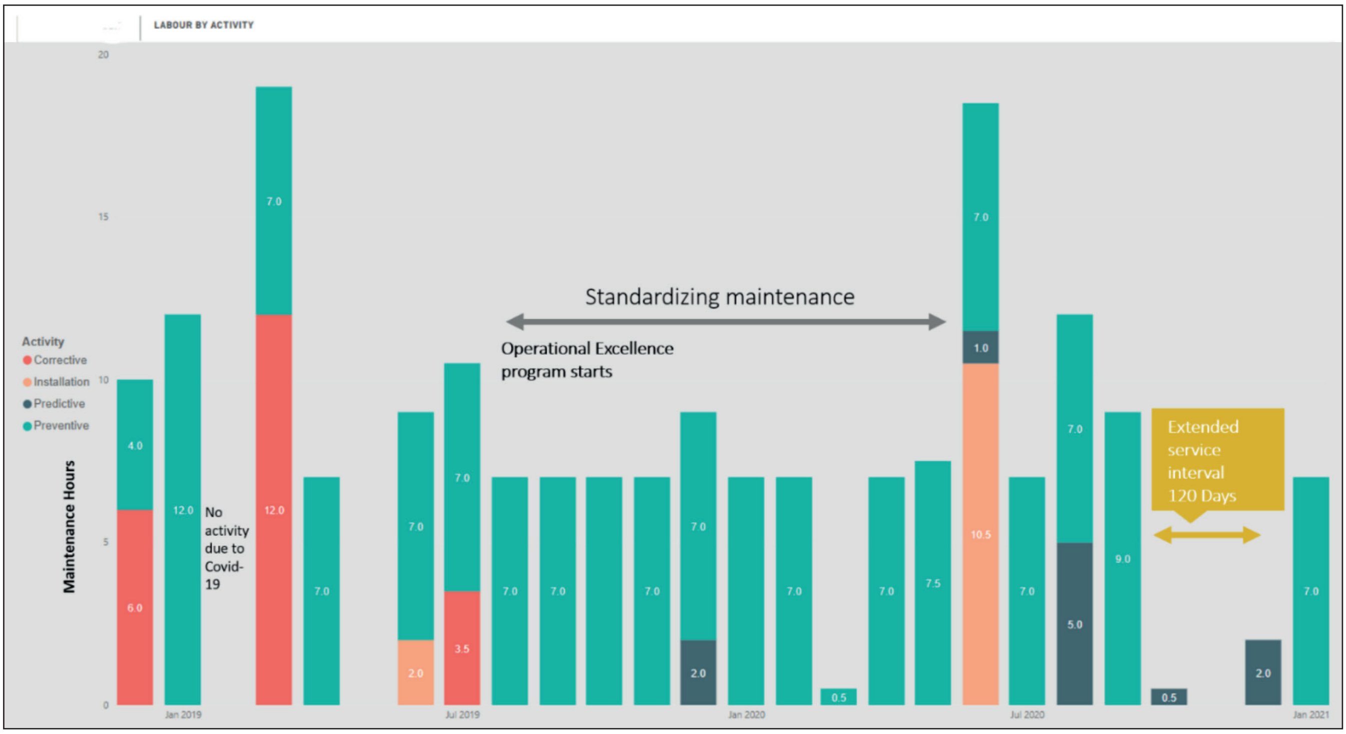


Fig 3. Results of program to enhance uptime – see text for explanation.

constantly review how their equipment is behaving and adjust maintenance activities accordingly, an ideal setting for a prescriptive maintenance approach. At this stage the fab is fully staffed. Fab personnel are trained and have gained enough experience to begin looking for ways to reduce maintenance costs and increase profitability. This is usually the time when fabs consider shifting away from reliance on equipment manufacturers to perform maintenance. The incentive grows to bring maintenance in-house to reduce costs. If equipment manufacturers wish to play a continuing role in maintaining a mature fab's equipment, they must demonstrate the value added by their domain knowledge and expertise. This requires a critical shift for both user and provider. Each must understand and accommodate shifting priorities as the fab matures. Providers must emphasize the unique contributions their knowledge and expertise allow them to make. Users must move from a model that views service as a cost to be avoided, to a model viewing service as an investment that yields returns from increased productivity. Mechanisms to achieve these goals include continuing improvement programs and predictive, adaptive, data-based interventions.

Providers must clearly demonstrate how their unique, knowledge-based value can make contributions to the user's bottom line that exceed any cost savings the user might realize from a lower hourly rate offered by a third-party provider or in-house personnel.

A "declining fab" is in survival mode; cost reduction is the name of the game as it fights to prolong its life and the jobs of the work force. Still, there is an opportunity for smart service management to support the goals of fab management and personnel. A fab at this stage has been running for a long time. The behavior and performance of its tools and the supporting equipment in the SubFab should be well understood. Based on data gathered over a lifetime of supporting, repairing, and refurbishing their systems, equipment manufacturers are in the best position to understand the maintenance requirements of the declining fab. With this unique knowledge, they can design a program that shares risks to reduce cost but still provides reliable performance to the user and reasonable compensation to the provider.

Collaboration

One trend that runs consistently from bottom to top, through all levels of the service maturity model, is the need for increasing collaboration between user and provider. Field service engineers comment frequently on its importance: close collaboration over time builds shared commitment to continuous improvement and the intimate understanding of the user's process and goals.

At the highest level of the service maturity model, users and providers can structure service programs that share risks and benefits, such as outcome-based contracts. This is the other end of the spectrum from time and materials billing. To work, the user must allow access to relevant context information and the provider must be open about process impacts on equipment performance. Ultimately, user and provider agree on the optimal outcome. The user benefits from known, stable maintenance costs and guaranteed performance. The provider is free to deliver that performance in the most efficient and profitable way. Each must trust the other's ability and commitment to make the program work.