300 mm Factory Layout and Material Handling Modeling: Phase II Report

International SEMATECH
Technology Transfer # 99113848B-ENG

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Abstract: This report describes the follow-up activities to Phase I of the 300 mm Factory Modeling Project. This report covers the approaches used in setting up the base model as well as selected experimental results. Models were run to compare the results of variations to the factory layout, non-product wafer loading, hot lot loading, automated material handling equipment downtime, buffer capacities, and number of stockers.

Keywords: Factory Modeling, Fab Design, 300 Mm Wafers, Equipment Performance, Equipment Modeling, Automated Materials Handling

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1 EXECUTIVE SUMMARY

A modeling project was started in May 1998 with the objective of using discrete-event simulation modeling to develop an understanding of factory operational issues associated with the newly developed 300 mm supplier guidelines and metrics. This modeling activity was designed to give the International SEMATECH (ISMT) member companies guidance in making decisions about future factory layouts and options by providing insight into their effects on factory productivity.

The first phase of the project was completed in March 1999 with the publication of *300 mm Factory Layout and Material Handling Modeling: Phase I Report* (Technology Transfer #99023688B-ENG). Phase II activity was begun to work on the next steps outlined in the Phase I report. The first objective of this follow-up activity was to build a more flexible generic model based on Phase I layouts and learning. The improved model increased the rate at which model layouts and automated material handling system (AMHS) strategies could be altered and facilitated comparisons between factory scenarios. The second objective was to run comparative experiments with this base model to determine the sensitivity of various detractors and the impact of factory options on cycle time, work in process (WIP), and utilization. This report covers the approaches used in setting up the base model as well as selected experimental results.

The model presented in this report is a highly idealized view of a generic 300 mm factory; therefore, the output for the model runs should not be viewed as comparable to any real production factory. The value of the model output is in the relative performance of the simulated factory as a function of input parameter selections.

Several modeling approaches developed in this activity may be of interest to other modelers. These include flexible factory layout and data entry, tool models (including single wafer and batch tools and loadports and internal buffers), front opening unified pod (FOUP) dispatching, AMHS equipment models, and AMHS downtime.

The base model includes several detractors (i.e., aspects of a factory that would adversely affect its performance). Detractors considered here include AMHS performance, process flows/multiple products, tool downtime, tool setups, pre- and post-processing times, tool loadport quantity and/or buffer size, tool batch size, batch tool models, hot lots, and non-product wafers (NPWs). The base model also includes several factory options. These are aspects of a factory, such as the layout or the modes of interbay and intrabay transport, that must be included in the model. Because each may take several forms, they are called factory options. The option considered here is factory layout.

Experiments have been developed to test the effects of varying detractors and factory options on factory performance. Experiments include changing the levels of NPWs, AMHS downtimes, and hot lots; changing factory layout to Farm and Modified Hybrid; altering the size of the internal buffers at batch tools; and changing the number of stockers per bay.

2 INTRODUCTION

Collaborative efforts by global semiconductor manufacturers have paved the way for the 200 mm to 300 mm wafer manufacturing transition by driving standardization of equipment and demonstrating equipment readiness. To facilitate the conversion, the International 300 mm Initiative (I300I) Productivity and Infrastructure department put together a team of ISMT member company engineers and modelers to work on the 300 mm Factory Modeling Project. The project started in May 1998 with the objective of using discrete-event simulation modeling to develop an understanding of factory operational issues associated with the newly developed 300 mm supplier guidelines and metrics.

The report *I300I Factory Guidelines* (Technology Transfer #97063311G-ENG) defines equipment standardization and factory vision, while *180 nm Equipment Performance Metrics-Revision 1* (Technology Transfer #97093360C-ENG) and *Metrics for 300 mm Automated Material Handling Systems (AMHS) and Production Equipment Interfaces: Revision 1.0* (Technology Transfer #97123416B-TR) define critical equipment attributes and goals. This modeling activity was designed to give the ISMT member companies guidance in making decisions about future factory layouts and options by providing insight into their effects on factory productivity.

The first phase of the project was completed in March 1999 with the publication of *300 mm Factory Layout and Material Handling Modeling: Phase I Report* (Technology Transfer #99023688A-ENG). At the conclusion of the Phase I activity to understand the impact of different high-volume manufacturing layouts, Phase II activity was begun to work on the next objectives outlined in the Phase I report. The first objective of this follow-up activity was to build a more flexible generic model based on the Phase I layouts and learning. The improved model decreased the time to alter model layouts and AMHS strategies, and facilitated comparisons between factory scenarios. The second objective was to run comparative experiments with this base model to determine the sensitivity of various detractors and the impact of factory options on cycle time, WIP, and utilization. This report includes the approaches used in setting up the base model, as well as selected experimental results.

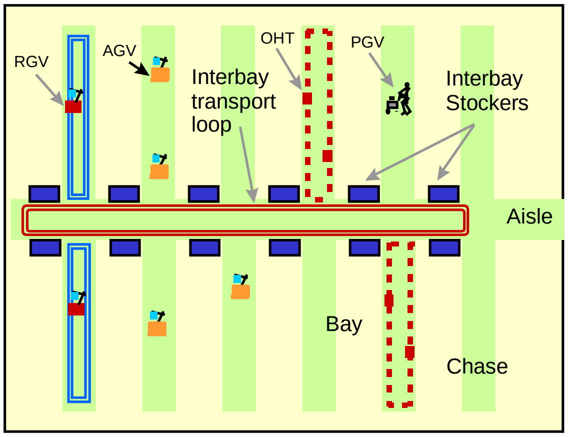
2.1 300 mm Factory Vision

In early 1996, I300I began developing a vision for 300 mm factories; its initial factory integration vision was expressed in the original *I300I Factory Guidelines*. Experience and learning in the industry have led to expansion and clarification of the fundamental tenets in the original guidance document, which has evolved into Version 5.0 (Technology Transfer #97063311G-ENG).

In the general layout envisioned for 300 mm factories, equipment is located in several bays that stem from a central aisle. A storage buffer (stocker) resides at the junction of the main aisle and each bay. Each bay also has its own central aisle with space for equipment on either side of the aisle. This type of layout lends itself to an AMHS format that consists of two different types of transportation, interbay and intrabay.

Interbay transportation must be used to transport wafers from one bay to another. Common in today’s factories, interbay transport uses standard wafer carriers that transport wafers between factory bay stockers by an overhead rail transportation system. This interbay material handling system is a loop that spans the central aisle of the factory and connects to all bays at their respective stockers.

In contrast, an *intrabay* transport system moves wafers between pieces of equipment within a single bay. An example is an overhead hoist transport (OHT) system that travels on an overhead monorail loop around a bay, carries standard wafer carriers, and lowers the carriers to an interface in front of the appropriate manufacturing equipment. This type of system also would interface with the bay's stockers at the head of the bay, as shown in Figure 1.



Note: AGV = Automatic Guided Vehicle
OHT = Overhead Hoist Transport
RGV = Rail Guided Vehicle
PGV = Person Guided Vehicle

Figure 1 I300I Vision of a 300 mm Factory AMHS

2.2 Approach

To model future factories through simulation, different factory layouts for 300 mm factories initially had to be designed. Three were developed: Farm, Hybrid, and Modified Hybrid, as defined in the Phase I report. Then, AutoSched/AutoMod models were built for each factory layout. These models were run for a factory starting 20,000 wafers (300 mm) per month with a single 180 nm logic process. Experiments were run on the models to compare the effects on factory productivity as defined by cycle time, WIP, and utilization. The models were run to compare the results of variations to the factory layout, non-product wafer loading, hot lot loading, automated material handling equipment downtime, size of the internal buffers at batch tools, and number of stockers.

The model presented in this report is a highly idealized view of a generic 300 mm factory; therefore, the output for the model runs should not be viewed as comparable to any real production factory. The value of the model output is in the relative performance of the simulated factory as a function of input parameter selections.

2.3 Future Work

The Semiconductor Industry Association (SIA) activity to develop the 1999 *International Technology Roadmap for Semiconductors* has identified possible next-generation automated material handling concepts for 300 mm factories. OHT systems such as those included in the current 300 mm factory model outlined in this report may not meet the longer-term throughput requirements of future factories. Two concepts have been proposed to increase factory productivity in future generations: integrated interbay/intrabay transport systems, and conveyor transport systems. In order to understand the effects of these next-generation systems, each type will be modeled to compare factory performance to that of the existing OHT systems, with the goal of identifying performance benefits or problems in order to focus development on the "best of breed" systems required for future high-production factories.

3 ASSUMPTIONS

Below is a list of the assumptions used in development of the base factory model.

3.1 Layout Assumptions

These assumptions were as follows:

1. 300 mm factory running 20,000 wafer starts per month (wspm). The actual simulation starts 27 regular lots (with 25 wafers per lot) and two NPW lots (one wafer per lot) each day. In addition, one hot lot is started every three days. Running seven days a week, that is approximately 4,797 wafer starts per week or 20,788 wspm.
2. Operation is 24 hour by 7 days per week.
3. I300I's single aluminum process flow at 180 nm technology. This determined the type of process equipment required.
4. The main aisle and perimeter aisle size (8 ft. [2.4 m] wide) was chosen by the team to accommodate interbay automated WIP transport with a single-level, one-directional loop.
5. The intrabay transport system is an OHT with one stocker per bay.
6. Spacing between tools and maintenance aisle widths were set to minimum 3 ft. (0.91 m) (e.g., clearance required for equipment maintenance) and 6 ft. (1.83 m) between wet benches.
7. Bay aisle widths were set to 10 ft. (3.05 m), including equipment loadports. This is based on the assumption that process tools are removed and brought in through the bay aisles, not the service chases/aisles. The bay lengths were set to 100 ft. to support factory egress rules.
8. Tool areas include all necessary support equipment (including internal buffers, resist cabinets, etc.) needed on the main floor. Other support equipment (e.g., pumps, chillers, etc.) were assumed to be mounted in the basement or other adjacent non-cleanroom space, and were not included in the factory layout.
9. This layout contains only production equipment, associated support equipment, AMHS stockers, and AMHS equipment. To get a more accurate representation of an actual 300 mm factory, other items should be considered, such as gown rooms, diffusion tube cleaning, FOUP cleaning, etc.
10. Reticle handling was not simulated, but the layout assumed that reticles were stored in reticle stockers and handled by a reticle AMHS to/from lithography equipment.
11. There is one stocker in each bay.

3.2 Modeling Assumptions

These assumptions were as follows:

1. The process flow is SEMATECH's 300 mm aluminum process flow for 180 nm technology with six metal layers, 21 masks, 43 tool types, and 316 steps. The raw process time for this process flow is 8.9 days.

2. Lot releases: Nine lots of 25 wafers are started every 8 hours. In addition, two single-wafer NPW lots are released every 24 hours, and one 25-wafer hot lot is released every 72 hours.
3. Hot lots follow the same routing as regular lots and are given priority over every other lot type at all tools.
4. NPWs follow the same routing as regular lots and are not given priority at any step, except for the normal dispatching rules described in assumption 11 below.
5. Each stocker has unlimited capacity.
6. Equipment throughputs are based on member company input.
7. Process times are entered as constant values. There is no variability in processing time.
8. Wafer sampling rates are based on 200 mm technology. The throughput values for these tools have been increased to reflect that only some of the wafers are inspected.
   - Manual inspection tools (visual scopes) sampling rate is two wafers per 25-wafer lot.
   - Automated metrology tools sampling rate is three wafers per 25-wafer lot.
9. Implant equipment is dedicated to specific process steps, based on species assignment. Also:
   - All implant process steps are dedicated to specific implanters (one-on-one), except for two process steps.
   - Both boron implant process steps are run on one implanter with a 15 min. setup time between each lot for an energy change (i.e., 250K Ev to/from 50K Ev).
10. Lithography process time includes an even distribution of setup times (i.e., setup every four lots distributed over each lot).
11. Dispatching rules are as follows:
   - Hot lots always have priority over all other lot types.
   - The implant and lithography areas use the “same setup” rule (i.e., the factory host seeks out the oldest lot in the stocker that requires the same processing setup as the previous lot run at the specific tool) as first priority and then first-in, first-out (FIFO) if there are no hot lots at the stocker.
   - If no hot lots are present at the stocker, all other areas dispatch lots from stockers to tools according to FIFO.
12. Batching rules: batches are formed at stockers and must be made up of lots from the same previous process step. No lots will be sent to a tool until at least a minimum batch is formed at the stocker. This prevents the tool from being “frozen” (i.e., dedicated to whatever lot was at the tool), unable to look at other forming batches, and waiting for the rest of the lots to arrive at the tool before it can begin processing. Also:
   - Automated wet cleans are processed in batches of two like lots per batch. Unless a hot lot is available, these tools always wait for two lots to be available at the stocker before the lots are batched and sent to the tool. If a hot lot is waiting at the stocker for this tool, the tool looks for another lot at the stocker to be batched with the hot lot. If no appropriate lots are present, the hot lot is sent to the tool and processed alone.

– Furnaces process batches of two to four like lots. Unless a hot lot is present in the stocker, once the minimum of two lots are present at the stocker, the tool will wait for up to half the process time for up to two more lots to become available at the stocker. If a hot lot is present at the stocker, the furnace looks for up to three more lots at the stocker to batch with the hot lot. If no other lots are available, the hot lot is sent to the furnace and is processed alone.

13. The model assumes that no rework takes place and that there is no yield loss.
14. Tool failures (unscheduled downtimes) are entered for every tool in terms of mean time between failure (MTBF) and mean time to repair (MTTR). Both are modeled with exponential distributions. Values are based on member company inputs.
15. Tool preventive maintenance (scheduled downtime) is entered for every tool in terms of mean time between preventive maintenance (PM) and mean time to complete a PM procedure. Both are modeled with triangular distributions. Values are based on member company inputs.
16. In the AMHS, both vehicles and stockers have unscheduled downtimes.
17. The interbay system is assumed to be a one-directional, single-loop overhead system. Vehicles are capable of carrying one lot at a time.
18. The intrabay transport system is assumed to be a one-directional OHT system. Each vehicle is capable of carrying one lot at a time.
19. On both the interbay and intrabay transport systems, empty vehicles move continuously until reaching a point where a FOUP is ready to be transferred onto a vehicle or blocked by another vehicle.
20. Due to the size of tool loadports, only one vehicle at a time is allowed access to a tool. Vehicles that want to pass a tool or gain access to a tool's loadport must wait until the space in front of the loadport is free of vehicles before moving to the tool.

4 MODELING APPROACHES

There are several aspects to this model for which the modeling approach is of interest. The following are the model approach deliverables for this project:

1. Flexible factory layout
2. Flexible data entry
3. Tool models
   - 3.1 Loadports, additional buffer
   - 3.2 Single-wafer, batch tools
4. FOUP dispatching
   - 4.1 Task selection
   - 4.2 Tool prioritization
5. AMHS equipment models
   - 5.1 Stockers
   - 5.2 Overhead transport
6. AMHS downtime

4.1 Flexible Factory Layout

The factory model consists of 24 bays. There are 12 bays on each side of the factory with an aisle running down the middle (see Figure 2). Three layout configurations have been designed for this project, the Farm, Hybrid, and Modified Hybrid. In the Farm layout, all like tools are placed together in the same bay or set of bays. Thus, there is a separate set of bays to hold the metrology tools. Each bay or set of bays holding like tools is designated a *functional area*.

The Hybrid layout is derived from the Farm layout by distributing metrology tools among the bays. If up to three metrology steps follow a step that utilizes a tool within a given bay, the necessary metrology tools are located in that bay. In the Modified Hybrid layout, in addition to the metrology tool redistributions, ashers and wet benches were also distributed among the various bays. Placing tools within a bay can be done via spreadsheet. Within each functional area, there may be several bays and many locations within each bay where tools may be placed. A workbook of several Excel worksheets contains all the necessary tools to aid in deciding where to place a tool. The first worksheet gives all of the dimensions of each tool's footprint. The next worksheet calculates the amount of wall space necessary to accommodate each type of tool. The third worksheet calculates the number of bays necessary to hold all of the tools in each functional area. The final worksheet is used to assign tools to bays. This worksheet keeps track of which control points have been assigned to each tool and how much space has been used in each bay. When tool assignments have been made, the information is transferred to the AutoSched station file. This file defines tools in the model and assigns them to locations (control points).

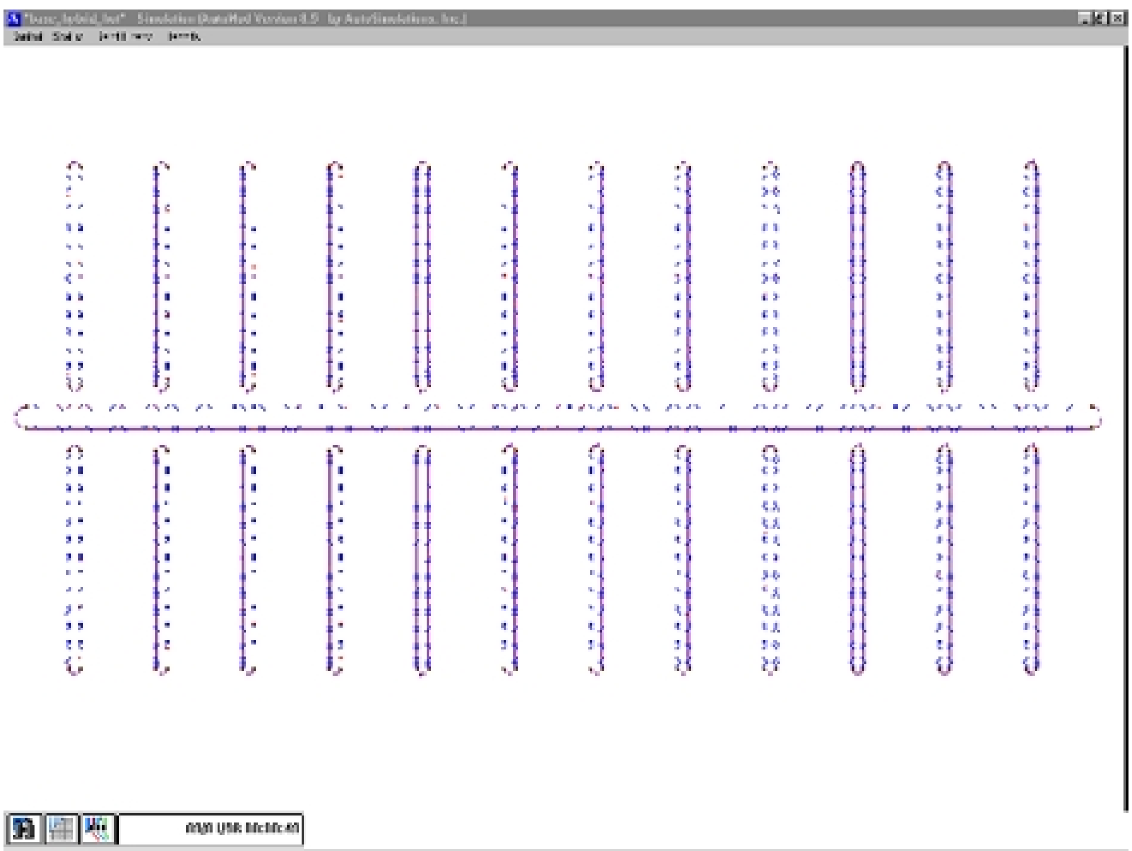


Figure 2 Factory Layout

4.2 Flexible Data Entry

Data entry into AutoSched is done via spreadsheet. For instance, the AutoSched station file allows the user to enter tools, tool locations, and batch sizes. In addition to spreadsheet data entry, AutoSched allows the user to add code written in the AutoSched programming language, AutoMod. The base model includes code of this sort. Most of the parameters used in this code can be changed in the AutoSched spreadsheets. For instance, each stocker is modeled with a resource to represent the stocker robot. This robot takes 15 seconds to move a lot from an input/output (I/O) port to a stocker shelf. The AutoMod code reads this value from the station file. Thus, in order to change the time from 15 seconds to, for example, 20 seconds for a given stocker, the value can be changed in a spreadsheet rather than searching through the code to find the appropriate line to change. Throughout the model, parameters for features of the model that had to be modeled via AutoMod code because they are not standard to AutoSched are entered through one of the standard AutoSched spreadsheet files.

4.3 Tool Models

All tools are modeled as one of three general tool types:

1. Single-wafer processing tool
2. Furnace tool
3. Wet bench tool

Each tool model contains the following operations (see Figure 3):

1. Buffer (loadports and internal FOUP buffers, as required)
2. Pre-process operation: represents reading the bar code, opening the pod door, docking, etc.
3. Processing operations (one or more depending on tool type): represents loading wafers into the tool, processing wafers, and unloading the wafers from the tool
4. Post-process operation: represents closing the pod door, reading the bar code, undocking, etc.

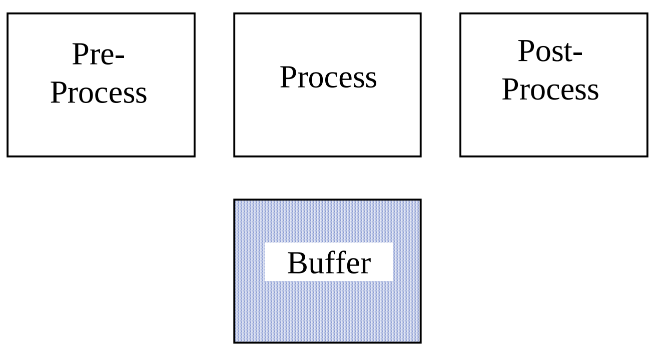


Figure 3 General Tool Model

4.3.1 Loadports and Additional Buffer

All tool models have a buffer that represents either the loadports or, as required, an additional buffer (see Figure 4). When a tool has additional buffer space, the modeled tool buffer is given a capacity that represents only the buffer space. In this case, the loadports are not explicitly modeled. Instead, arriving lots are immediately deposited in the buffer and departing lots move directly from the buffer to a vehicle. Since loadports would not be used to store FOUPs when a buffer is available, explicitly modeling the loadports is not necessary.

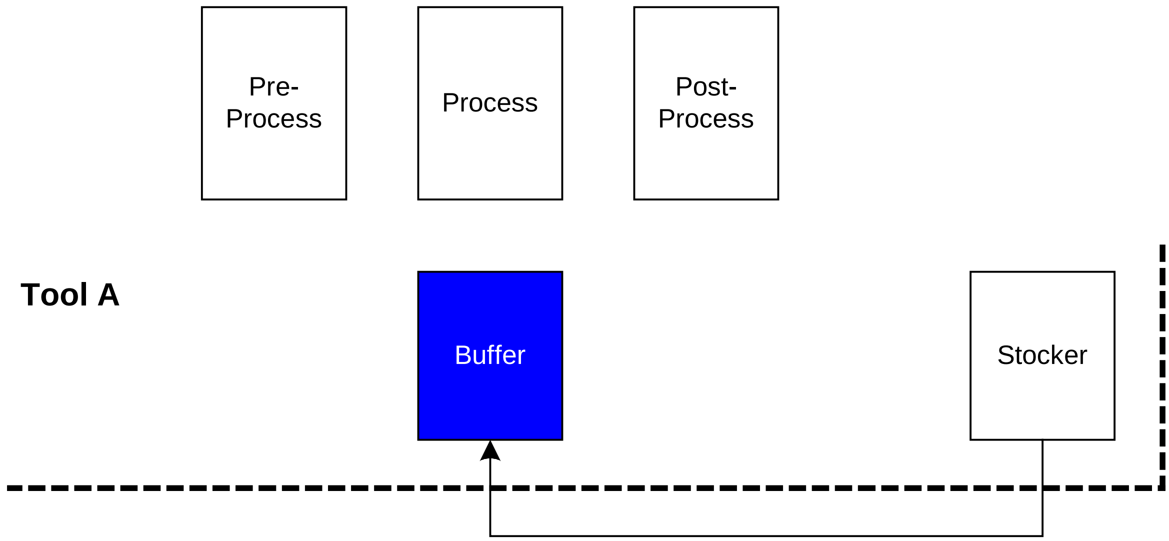


Figure 4 Tool Buffer

A lot's FOUP remains in the buffer from the time the lot is dropped off by a vehicle until the time it is picked up by another vehicle upon completion of processing. While the wafers in a lot are being processed, the FOUP takes up a space in the buffer.

4.3.2 Single-Wafer Tool Models

The single-wafer tool model described here can represent most of the tools in the model. All tools that process a single lot one wafer at a time are modeled with this tool type. There are three operations at this type of tool (see Figure 5):

1. Pre-process Operation
   - Represents preparing the FOUP for the tool
   - Pre-processing time (20 seconds)
2. Process Operation
   - Represents processing the lot
   - Process times are based on member company provided throughputs
3. Post-process Operation
   - Represents preparing the FOUP for the AMHS
   - Post-processing time (20 seconds)

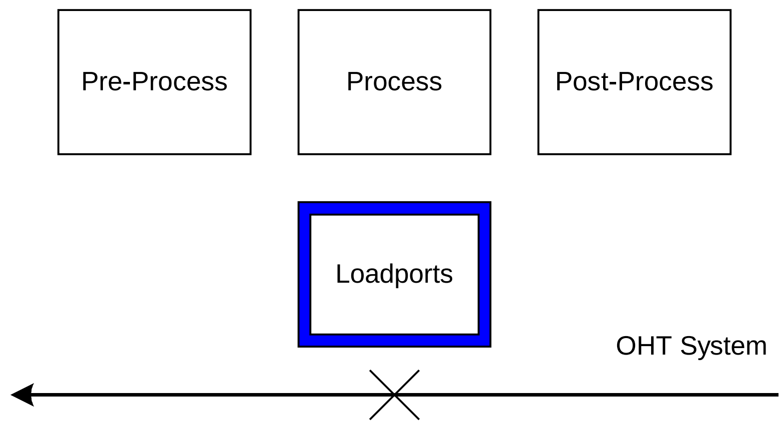


Figure 5 Single-Wafer Tool Model

The pre-processing and post-processing operations are modeled as independent operations that can run at the same time as the processing operation. That is, there can be a lot in the pre-process operation, one lot in the process operation, and one lot in the post-process operation simultaneously. This helps to prevent the tool from being starved. The pre-process operation performs the task selection operation. That is, it calls lots from the stocker to the tool when the pre-process operation is idle and there is space in the buffer. An arriving lot immediately enters the pre-process operation. The pre-process operation is short compared to the process time of the tool, so if the process operation is busy with another lot, the arriving lot will usually complete the pre-process operation before the process operation becomes idle. As a result, the arriving lot will be available to the process operation as soon as the lot that is being worked on completes processing and enters the post-process operation.

The pre-process, process, and post-process operations all are modeled with AutoSched stations. For a given tool, the pre-process, process, and post-process stations are linked to ensure that each lot is processed completely by a single tool.

4.3.3 Furnace Tool Models

All furnaces are modeled with the furnace tool model described here. There are four operations at this type of tool (see Figure 6):

1. Pre-process operation
   - FOUPs are moved into the additional buffer and prepared for the tool
   - Pre-processing time (40 seconds)
2. Process #1
   - Wafers are loaded into the boat
   - Batches of two, three, or four FOUPs are processed
   - Process times are based on member company input
3. Process #2
   - Batch is cooled down
   - Wafers are unloaded from the boat
   - Process time is 30 minutes

4. Post-process operation
   - FOUPs are returned to the buffer, prepared for the AMHS, and moved onto the loadport
   - Post-processing time (40 seconds)

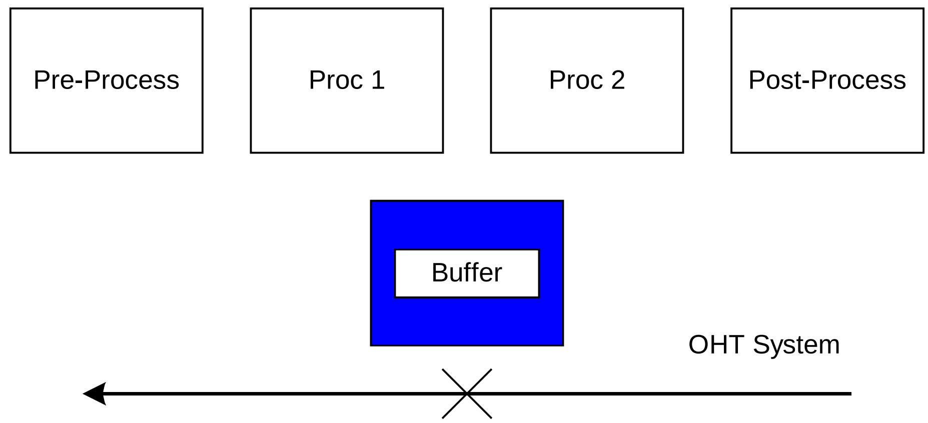


Figure 6 Furnace Tool Model

As in the single-wafer tool model, the pre-process and post-process operations can operate while the process operation is processing another lot. This helps prevent tool starvation.

Furnace tools process batches of two, three, or four FOUPs. Batches are formed at the stocker, so the tool does not call lots until a batch is formed. Once a batch is formed, the lots in the batch are transported individually on the intrabay transport system. Once the entire batch has reached the tool and entered the buffer, the batch enters the pre-process operation. Upon completing the pre-process operation, the batch waits for the first process operation to become idle. When the first process operation is available, the batch immediately begins processing at the first process operation. The processing time at the first station ranges from 170 to 370 minutes, depending on the type of furnace required. This processing time at the first processing operation is longer than the processing time at the second processing operation. So, the second process operation (the cooldown operation) will always be free by the time the batch finishes processing at the first operation. Thus, the lot immediately enters the cooldown operation upon completing the first processing operation. Finally, when the batch is cooled down, it enters the post-process operation.

The pre-process, first process, and post-process operations are modeled as AutoSched stations. The stations are linked so that each lot is completely processed at a single station. The cooldown process is not modeled by a station. Instead, upon completing processing at the first process station, the batch is told to wait for 30 minutes before entering the post-process station. As noted in the paragraph above, the processing time at a furnace is longer than the cooldown time of 30 minutes, so there can be at most one lot in the cooldown state at any time. The process station becomes idle as soon as the batch begins its cooldown time.

4.3.4 Wet Bench Tool Model

All wet benches are modeled with the wet bench tool model described here. Wet benches are assumed to have four baths. There are six operations at this type of tool (see Figure 7):

1. Pre-process operation
   - FOUPs are moved into the buffer and prepared for the tool.
   - Process time is 40 seconds.
2. Process #1
   - Wafers are loaded into the rack.
   - A batch of two FOUPs is processed.
   - Process time is based on member company input.
3. Process #2
   - A batch of two FOUPs is processed.
   - Process time is based on member company input.
4. Process # 3
   - A batch of two FOUPs is processed.
   - Process time is based on member company input.
5. Process #4
   - A batch of two FOUPs is processed.
   - Wafers are unloaded from the rack.
   - Process time is based on member company input.
6. Post-process operation
   - FOUPs are returned to the buffer, prepared for the AMHS, and moved to the loadport.
   - Process time is 40 seconds.

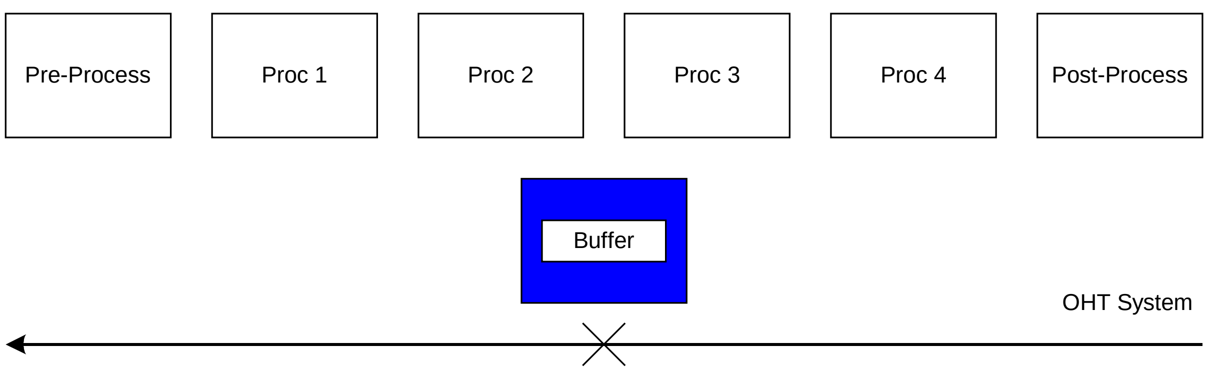


Figure 7 Wet Bench Tool Model

As with the single-wafer and furnace tool models, the pre-process and post-process operations can occur while the process operations are processing other lots. Up to eight lots (four batches of two lots each) can be processed in the baths at the same time. In addition, one more batch may be in the pre-process operation while another batch is in the post-process operation. Batches are formed at the stocker and are then transported, one FOUP at a time, by the intrabay transport system to the tool buffer. Once the entire batch is placed in the buffer, the batch begins the pre-process operation. The batch then waits for the first process operation to become idle. Each process operation has exactly the same process time. The time for a single batch to go through all four baths is based on member company inputs. This processing time ranges from 17.6 to 20 minutes, depending on the tool type and processing step. The process time is divided equally among the four bath process operations. Upon completing all four baths sequentially, the batch enters the post-process operation.

Similar to the furnace tool model, the pre-process, first process, and post-process operations are all modeled by linked AutoSched stations. The second, third, and fourth process operations are not modeled by stations. Instead, upon completing the first process operation, the batch is instructed to wait for the length of the other three bath operation before entering the post-process station. Because each bath is given equal process time, this effectively models each lot moving sequentially through the four baths. The first process station becomes idle as soon as the batch completes the first bath process time.

4.4 FOUP Dispatching

4.4.1 Task Selection

A FOUP residing in a stocker is *task selected* when a tool claims the FOUP for its empty buffer or available loadport. A tool will not task select if its buffer is full. As described earlier, the pre-process operation actually performs task selection in order to minimize tool starvation.

A tool task selects a FOUP in two instances:

1. Every time a FOUP enters a stocker, a defined set of downstream tools is alerted by the FOUP. In turn, those downstream tools with available loadport or buffer space start the task selection process.
2. Every time a FOUP leaves a tool, the task selection process is activated. In this case, all the tools of the family from which the FOUP has departed try to select a FOUP from their family stocker.

4.4.2 Tool Prioritization

Consider a lot being routed to its next process step. If any tools appropriate for that step are located in the same bay as the lot, priority is given to the tools within that bay. If a tool in the bay is available when the lot returns to the stocker, the lot will be claimed by that tool. If no appropriate tools within that bay are available, the lot will wait in the stocker for up to five minutes for a tool to become available. After this time elapses, the lot can be task selected by any available tool in the factory. A round robin algorithm is used to determine which of the available tools in the factory task selects the lot at this point.

If a hot lot is sent to a tool that either fails or becomes busy while the hot lot is on its way, the hot lot can be sent back to the stocker to repeat the task selection process. If there are no other tools in the factory that can perform the process that the hot lot needs, the hot lot will stay at the tool and wait for the tool to be repaired or to finish its current task. If there are other tools that can perform this step, the hot lot will be sent back to the stocker to go through task selection again. It can immediately be task selected by any available tool in the factory. This prevents a hot lot from being stuck at a busy or down tool when it could be in process at another tool.

4.5 AMHS Equipment Models

There are 25 separate transport systems in the model: 24 intrabay systems (one for each of the 24 bays) and the interbay system that spans the center of the factory. Each AMHS modeled consists of three types of entities: tracks, vehicles, and stockers. Vehicles travel the interbay and intrabay transport tracks and interact with tool loadports and stockers.

4.5.1 AMHS Track Model

The interbay and intrabay tracks are laid out as one-directional loops. Vehicles travel each of these loops as they move between tools and stockers. Each loop has a series of points at which vehicles may stop. In Figure 8, these points are represented by the X's labeled "in" and "out" below the tool and stocker on the intrabay loop. These points are called control points and they are the only points at which a vehicle may stop. In order to model worst-case behavior with respect to tools, vehicles passing a tool first pass the out-control point and then the in-control point. Thus, a vehicle cannot drop off a lot and pick up a new lot on the same visit to a tool. Instead, after dropping off a lot, a vehicle must complete another trip around the loop and return to the tool to pick up another lot (unless another empty vehicle comes along and picks up the lot).

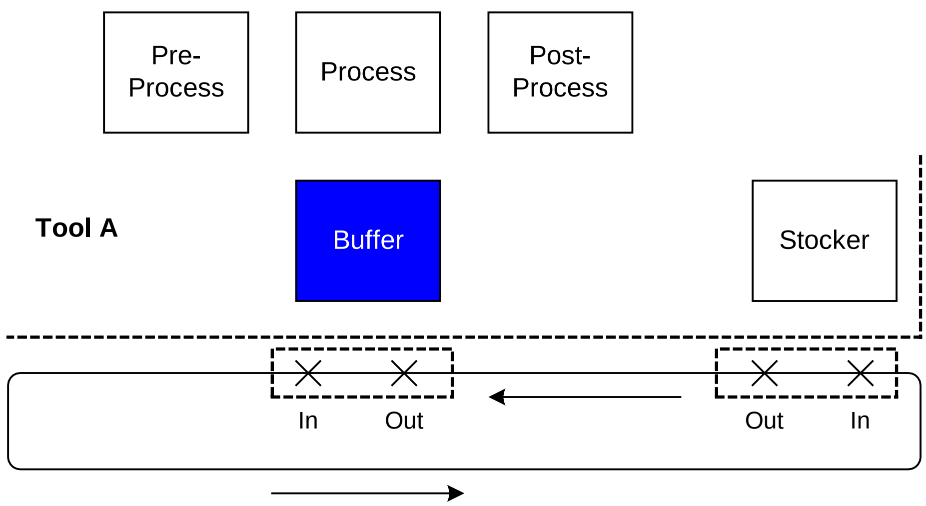


Figure 8 AMHS Tracks

Because of the limited size of tool loadports, there is not enough space for two vehicles to access a tool at the same time. To prevent this in the model, territories were created around each pair of control points in front of a tool or stocker. Each territory has a capacity of one vehicle. In Figure 8, the red boxes around the control points represent these territories. A vehicle that wants to enter a territory must wait until the territory is empty before entering. The vehicle will wait at the last control point before the territory that it wants to enter. If the control point at which the vehicle is waiting is inside a territory, the vehicle is taking up a spot in that territory. Thus, there can be a series of vehicles stopped at control points (one per territory) waiting for one vehicle to leave a territory.

In AutoSched, the interbay and intrabay systems are modeled with automated guided vehicle (AGV) systems. The tracks are one-directional loops. The control points all have a default capacity of one vehicle. The territories are created with AutoSched blocks. Each block is given a capacity of one vehicle.

4.5.2 Vehicle Model

Each vehicle in the model has a capacity of one FOUP. Vehicles are restricted to a single interbay or intrabay loop and circle the loop continuously when not stopped by other traffic or busy performing a task. At the beginning of the simulation run, each vehicle appears randomly at a location (control point) on its designated loop. Only one vehicle can appear at each control point at a time. Vehicles then begin circling the loop in search of work. At each control point, a vehicle will look for work if it is empty and check to see if it is time to have a failure. AMHS downtime will be discussed in Section 4.6. An empty vehicle passing a control point will check to see if there are any lots waiting to be picked up that have not yet claimed another vehicle. The vehicle looks for lots waiting to be picked up anywhere on its transport system. Once claimed by a lot, the vehicle continues to circle the loop until reaching the tool or stocker at which the lot is waiting. The vehicle will not look for work at any control points it passes on the way to pick up the lot. Similarly, once the vehicle has picked up a lot, it moves around the loop to the lot's destination, passing control points without checking for work. As described in the next section, a vehicle experiences a delay when picking up or dropping off a lot.

In AutoSched, vehicles are modeled with AGVs on each transport system.

4.5.3 Stocker Model

The vision of stocker operations modeled in the AutoSched model is pictured in Figure 9. Vehicles traveling along the interbay or intrabay system can stop at the stocker's input I/O port to pick up a lot or the stocker's output I/O port to drop a lot off. A single robot resource moves FOUPs to and from the I/O ports inside the stocker. All the I/O ports in a stocker share this robot.

In AutoSched, each stocker is modeled as a storage unit with infinite capacity. There are five resources associated with each stocker, four representing the I/O ports and one representing the robot arm.

Upon completing processing at a station, a lot is always moved from the station to a stocker. Even if a tool appropriate for its next processing step is available and located in the same bay, the lot will be sent to a stocker. Thus, no tool-to-tool moves are modeled. This approach models the worst case behavior of lot movement in which all tool loadports are always busy. Another advantage of not modeling tool-to-tool moves is that complicated task selection algorithms are avoided.

Stockers are modeled with infinite capacity. If a stocker were given a limited capacity and that capacity were reached, lots that want to be delivered to that stocker would have to be given other instructions. In order to avoid modeling a complicated rerouting process, stockers are modeled with infinite capacity. As shown later in this report, the maximum number of lots in any stocker is rarely more than 150 FOUPs and never more than 200 FOUPs in any of the steady-state models. In fact, with infinite capacity, the maximum number of lots in each stocker gives an indication of the stocker capacity needed at that point in the generic factory modeled.

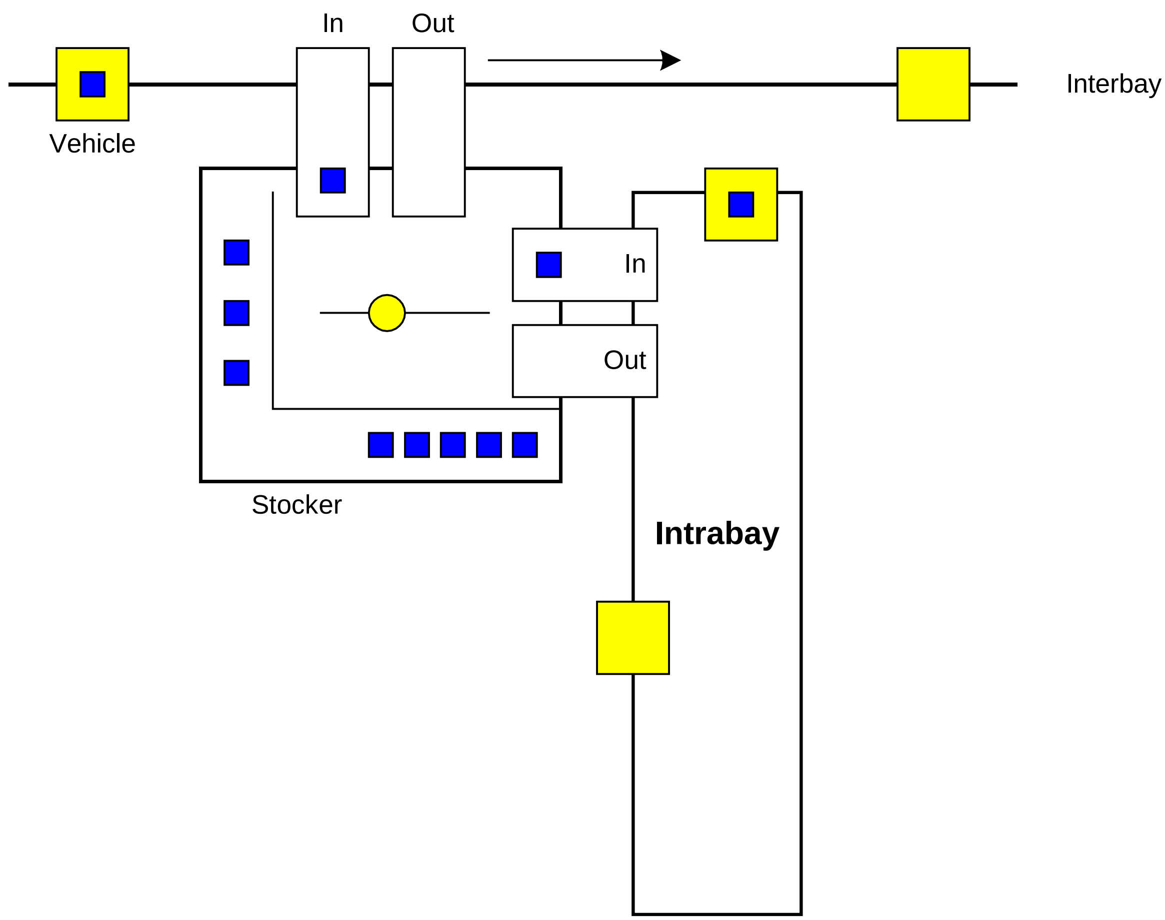


Figure 9 Stocker Operations

A vehicle dropping off a lot at a stocker in-port experiences a delay while the lot is transferred. This delay is 7 seconds for interbay vehicles and 20 seconds for intrabay vehicles. Once the lot is dropped off, the lot claims the in I/O port for the transport system from which it is being transferred (interbay or intrabay) and experiences a delay of 7.5 seconds for transfer onto the in-port. Once on the in-port, the lot claims the robot resource and frees the in-port resource. The robot takes 15 seconds to move the lot into the stocker. At this point (after being dropped off, experiencing the in-port delay, and experiencing the robot delay) the lot is available to be selected by a tool. If an in-port is busy with a FOUP, a vehicle carrying a FOUP destined for that stocker will wait until the FOUP on the in-port is picked up by the robot arm before the FOUP on the vehicle begins the unload process.

A lot that is ready to leave the stocker begins the move by simultaneously claiming the robot and the out I/O port for the transport system (interbay or intrabay) on which the lot will be moved. The robot again takes 15 seconds to move the lot from the stocker onto the out-port. The robot is freed as soon as the 15 seconds are complete. The out-port then takes 7.5 seconds to represent preparing the lot for the vehicle. The lot then waits on the out-port for a vehicle to arrive. Once a vehicle is ready to retrieve the lot, the lot frees the out-port and experiences a delay for being picked up by the vehicle. This delay is 7 seconds for interbay vehicles and 20 seconds for intrabay vehicles. If the stocker's out-port is busy with a FOUP, the robot arm will not pick up a

FOUP that is ready to leave the stocker. The FOUP will wait until it can reserve the out-port and then request transport by the robot arm.

4.6 AMHS Downtime

Both vehicles and stockers experience unscheduled failures. Based on member company consensus and the guidelines published in *Metrics for 300 mm Automated Material Handling Systems (AMHS) and Production Equipment Interfaces: Revision 1.0*, the mean time between incidents (MTBI) in the base model is 500 hours for both vehicles and stockers. The guidelines specify that the MTBI should be at least 500 hours. The time between failures is modeled by an exponential probability distribution with a mean of 500 hours. Based on member company input, the repair time for a vehicle is 5 minutes 80% of the time and 30 minutes 20% of the time. A 5-minute repair represents a failure in which a short action (such as a technician giving the vehicle a push to get it moving again) will repair the vehicle. A 30-minute failure represents a more extreme failure that requires an action such as replacing the vehicle with a working vehicle. It is assumed that on each interbay or intrabay system, the number of vehicles does not change during the simulation period. Stocker repair times are always 30 minutes.

At the beginning of the simulation, each vehicle is assigned its first failure and repair times. Each time a vehicle passes a control point (unless it is carrying a load), the vehicle checks whether its failure time has been reached. A vehicle carrying a load will not check its failure time at every control point due to AutoSched logic. The first time a vehicle pauses at a control point and finds that it has passed its failure time, it stops there for its assigned repair time. Other vehicles trying to move along the track will line up at control points behind the failed vehicle. As soon as its repair time has been exhausted, the vehicle begins moving again. A vehicle will also check its failure time when it arrives at a tool to drop off or pick up a lot and before it moves away from a tool after dropping off or picking up a lot. A vehicle discovering that it is time to fail before dropping off a lot will fail with the lot on the vehicle. Thus, both the vehicle and the lot are tied up by the failure. After each failure, each vehicle is assigned a new failure and repair time for its next failure.

Stockers fail on average every 500 hours. The stocker's robot resource is taken down to represent a stocker failure. As a result, all lots inside the stocker at the time of its failure must remain in the stocker during the failure. If the robot is transferring a lot when it fails, the lot continues to claim the robot for the entire failure and resumes transfer when the robot is brought back up. Because the I/O ports are not taken down when a stocker fails, if there is a lot on an out-port, a vehicle can pick it up. Similarly, if the in-port is free, a vehicle can deliver a lot to the in-port. The lot will not be transferred into the stocker until the robot is brought back up and completes the transfer it was working on before failing (if it was doing so).

If a vehicle tries to deliver a lot to the stocker and finds that the in-port is busy, the lot must be rerouted. If the lot is being moved on the intrabay system, the vehicle circles the bay until the stocker becomes available. If the lot to be delivered is on the interbay system, the vehicle begins circling the interbay system in search of an available stocker. The lot is delivered to the first available stocker the vehicle passes. The lot remains in the alternate stocker until the original stocker is available, at which point the lot is sent to the original stocker via the interbay system.

5 MODEL VERIFICATION

In order to confirm that the model works as intended, several verification procedures have been performed. First, the model was run without the AMHS system, tool failures, tool preventive maintenance events, or batching. A single 25-wafer FOUP was sent through this system. Because there are 316 steps in the process flow and each tool is modeled with three stations (pre-process, process, and post-process), the lot went through 948 steps. The expected utilization of each set of similar tools equaled the utilization given by the model, where:

$$\text{Expected Utilization} = \frac{\left(\dfrac{\text{Total time tool set spent processing}}{\text{Total simulated time}}\right)}{\text{\# of tools in set}}$$

The cycle time given by the model equaled the expected cycle time of the lot, where:

Expected Cycle Time = Sum of all FOUP processing times + setup times.

Next, a single 25-wafer FOUP was run through the model with no tool failures or PMs and no batching. The AMHS was turned on. Again, the FOUP was processed by 948 steps and the expected utilization equaled the utilization given by the model results. The cycle time check could not be used this time because the AMHS added transport delays to the cycle time. The FOUP used the transportation system before and after each process step resulting in 632 (316*2) move sequences. A move sequence consists of a move on the interbay, intrabay, or both systems.

6 REPLICATIONS

The member companies expressed an interest to have all experiments run five times for approximately 900 days. Unfortunately, the computers being used run out of memory and stop working around 700 days. Furthermore, it can take about three days to run a 700-day model. These two facts led the modeling team to investigate replication plans that did not involve running the model for 900 consecutive days.

AutoSched allows models to be restarted with a non-zero amount of WIP in the factory. AutoSched also allows the user to save the amount and location of WIP in the factory at a given time. This yields the opportunity to run the model for an initialization period and save the WIP in the factory at the end of that run. The model can then be restarted with that amount of WIP in the factory.

Two experiments were run and compared to check the performance of a model after such a restart. The first experiment was a single run of 400 days, while the second experiment consisted of four consecutive 100 day runs plus a final run of 300 days. The evolution of WIP in each simulation is shown in Figure 10. Table 1 shows the results of the run. The first column shows the results of the last 100 days of the last cycle of the restarted model. The second column shows the results of the last 100 days of the 400-day run. The last column shows the difference between the two columns.

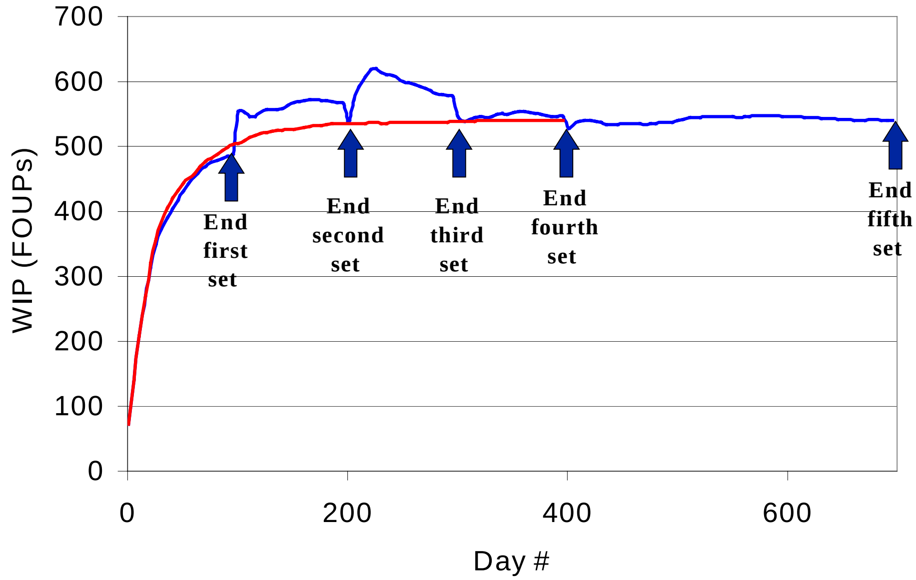


Figure 10 Model Restart Experiment WIP Evolution

Table 1 Model Restart Experiment Results

	Restart Model (Last 100 days of last cycle)	**No-Restart Model (Last 100 days)**	**Difference**
Cycle Time			
Average (days)	20.6	20.1	0.5
Std. Dev. (hours)	1.95	1.01	
WIP			
Average (FOUPs)	539.4	542.6	-3.2
Std. Dev. (FOUPs)	0.62	2.29	

The replication plan for most of the experiments presented in this report is as follows. A single run of 400 days is used as an initialization run. The WIP in the system is saved at the end of this run. Five more runs are started with this WIP in the system. These runs are 500 days each, resulting in a total run length of 900 days. Each of the six runs is started with different random streams so that the results of each run are independent.

7 MODEL PARAMETERS

The base model includes several detractors. Detractors are aspects of the factory that, when added, will adversely affect the performance of the factory. The model also contains several factory options. These are aspects of the factory that can be included in any of several forms. For instance, tools must be placed in the factory, but there are many ways in which the factory can be laid out. The factory designers can choose which layout they will use. The detractors and factory options considered here include the following:

- Factory layouts (Hybrid, Modified Hybrid, and Farm)
- AMHS performance (interbay, intrabay, and stocker)
- Process flows/multiple products (logic and dram)
- Tool downtime (failures and pms)
- Tool setups (litho and implant)
- Pre- and post-processing times
- Tool loadport quantity and/or buffer size
- Tool batch size (furnace and wet clean)
- Batch tool models (boats and baths)
- Hot lots
- Non-product wafers

Each of these detractors appears in the base model with a given value (or set of values), called the level of the detractor. Section 7 explains the levels at which the detractors appear in the base model. Section 8 describes the results of experiments that change the levels of one or more detractors.

7.1 Factory Layouts

The base model uses the Hybrid layout. In the Hybrid layout, metrology tools have been distributed among the bays according to the process flow. If one or more metrology steps follow a step for which the necessary tool is located in a bay, the appropriate metrology tools also will be placed in that bay. Metrology tools are the only types of tools distributed in this manner. All other tools are located in functional areas with similar tools.

While there are 24 bays in the model, only 23 bays are utilized in the base model. The functional areas and the tool types included in each functional area are described in Table 2. For more discussion on factory layouts, see *300 mm Factory Layout and Material Handling Modeling: Phase I Report.*

7.2 AMHS Performance

The interbay transport system, intrabay transport systems, and stockers each have their own sets of performance values.

The interbay system is assumed to be a one-directional, single-loop overhead system. Vehicles are capable of carrying one lot at a time with the following parameters:

- Straight velocity: 6.6 ft/s (2.01 meters/sec. [m/s])
- Curve velocity: 1.6 ft/s (0.49 m/s)
- Acceleration: 3.2 ft/s^2 (0.98 m/s)
- Lot handling time: 7 sec.

The intrabay transport system is assumed to be a one-directional OHT system. Each vehicle is capable of carrying one lot at a time and has the following parameters:

- Straight velocity: 5 ft/s (1.52 m/s)
- Curve velocity: 2 ft/s (0.61 m/s)
- Acceleration: 3.2 ft/s^2 (0.98 m/s)
- Lot handling time: 20 sec.

Both interbay and intrabay vehicles have unscheduled failures. The time between failures is exponentially distributed with a MTBI of 500 hours. The repair time is 5 minutes 80% of the time and 30 minutes 20% of the time. The 5-minute repair time models short failures (such as when a technician is required to give the vehicle a push to get it moving again). The 30-minute downtimes model failures that require more significant action (such as replacing the vehicle).

The number of vehicles included on each transport system is listed in Table 3.

Table 2 Functional Areas

Functional Area	Bay	Tool Types	# Tools
CMP	B	CMP_Ins_C	1
		CMP_Met_BEOL	5
		CMP_Met_FEOL	1
		Insp_PLY_BEOL	1
		Insp_PLY_FEOL	1
		Meas_Film_BEOL	1
		Meas_Film_FEOL	1
	D	CMP_Ins	1
		CMP_Ins_I	6
		Insp_PLY_BEOL	1
		Meas_Film_BEOL	1
CVD BEOL	V	CVD_Ins_I	9
		Insp_PLY_BEOL	1
		Meas_Film_BEOL	1
	X	CVD_Ins	1
		CVD_Ins_C	3
		CVD_Ins_Thin	2
		Meas_Film_BEOL	1
		Meas_Film_FEOL	1
Etch & Strip BEOL	O	Dry_Etch_I	12
	Q	Dry_Etch_Met	12
	S	Dry_Strip_I_FEOL	2
		Dry_Strip_I_BEOL	1
		Dry_Etch_I	3
Etch & Strip FEOL	K	Dry_Etch	8
		Insp_Visual	1
		Meas_Film_FEOL	1
	M	Dry_Etch_A	3
		Dry_Etch_C	2
		Dry_Strip	8
		Dry_Strip_D	2
Furnace & RTP	L	Furn_FastRmp	10
		Furn_Nitr	3
		Furn_Poly	3
		Furn_TEOS	3
		RTP_OxAn_C	3
		Meas_Film_FEOL	1
	N	RTP_OxAn	2
		Furn_OxAn_I_BEOL	19
		Furn_OxAn_I_FEOL	2
		Meas_Film_FEOL	1
Implant	A	Implant_HiE_1	2
		Implant_HiE_2	1
		Implant_HiE_3	1
		Implant_LoE_1	1
		Implant_LoE_2	1
		Implant_LoE_3	1
		Implant_LoE_4	1
		Implant_LoE_5	1
		Implant_LoE_6	1

Functional Area	Bay	Tool Types	# Tools
Metal Dep	P	PVD_Met	8
	R	CVD_MetW	6
		CVD_Met	7
	T	PVD_Met_C	2
		CVD_Met_C	2
		CVD_MetW_C	2
		Insp_Visual	1
Photolithography	C	Litho_248_BEOL	7
		Insp_PLY_BEOL	1
		Meas_CD_BEOL	2
		Meas_Overlay_BEOL	2
	E	Litho_Iw	4
		Insp_PLY_BEOL	1
		Insp_PLY_FEOL	1
		Meas_CD_BEOL	1
		Meas_CD_FEOL	1
		Meas_Overlay_BEOL	1
		Meas_Overlay_FEOL	1
		Litho_248_FEOL	4
	G	Litho_I_FEOL	7
		Insp_PLY_FEOL	1
		Meas_CD_FEOL	2
		Meas_Overlay_FEOL	2
	I	Litho_I_FEOL	2
		Litho_I_BEOL	5
		Insp_PLY_BEOL	1
		Insp_PLY_FEOL	1
		Meas_CD_BEOL	2
		Meas_CD_FEOL	1
		Meas_Overlay_BEOL	2
		Meas_Overlay_FEOL	1
Test	U	Test_1	19
Wet Area BEOL	F	Wet_Bench_I_BEOL	4
		Meas_CD_BEOL	2
		Insp_PLY_BEOL	1
	H	Wet_Bench_I_BEOL	3
		Wet_Bench_I_FEOL	1
		Insp_PLY_BEOL	1
		Meas_CD_BEOL	1
		Meas_CD_FEOL	1
Wet Area FEOL	J	VP_HF_Clean	4
		Wet_Bench	5
		Insp_PLY_FEOL	1
		Meas_CD_FEOL	2

Table 3 Number of Vehicles

System	Functional Area	# of Vehicles
Main		30
A	Implant	2
B	Chemical-mechanical polishing (CMP)	4
C	Photolithography	5
D	CMP	4
E	Photolithography	4
F	Wet Area Back End of Line (BEOL)	3
G	Photolithography	6
H	Wet Area BEOL	3
I	Photolithography	2
J	Wet Area FEOL	4
K	Etch & Strip Front End of Line (FEOL)	3
L	Furnace & Rapid Thermal Processing (RTP)	3
M	Etch & Strip FEOL	2
N	Furnace & RTP	4
O	Etch & Strip BEOL	2
P	Metal Dep	2
Q	Etch & Strip BEOL	2
R	Metal Dep	2
S	Etch & Strip BEOL	1
T	Metal Dep	1
U	Test	2
V	CVD BEOL	4
X	CVD BEOL	1
Total		**95**

There is one stocker in each bay in the base model. Stockers include two I/O ports on the interbay system, two I/O ports on the intrabay system, and a robot arm to transfer FOUPs between the stocker shelves and the I/O ports. The I/O ports cause a delay of 7.5 seconds and the robot arm causes a delay of 15 seconds to transfer a FOUP into the stocker. Similar to vehicles, stockers experience unscheduled downtimes. The robot arm fails with an exponentially distributed time between failures and a MTBI of 500 hours. All stocker repairs take 30 minutes.

7.3 Process Flow

A single aluminum 180 nm logic process flow is used in the base model. The flow has a raw process time of 8.9 days and 316 process steps. The process flow is given in the Appendix. For more details about the process flow, see *SEMATECH Generic 0.18 um Process Flows.*

7.4 Tool Downtimes

All tools in the model are subject to both unscheduled failures and preventive maintenance. Both daily and weekly preventive maintenance is modeled. The times between unscheduled failures as well as their repair times are exponentially distributed. The time between preventive maintenance events and the length of a preventive maintenance event are both triangularly distributed for both daily and weekly preventive maintenance. The parameters for all three types of downtime distribution for each tool are given in Table 4.

7.5 Tool Setups

All lithography tools have a setup of 12 minutes. Both boron implant process steps are run on one implanter with a 15-minute setup time between lots for an energy change when necessary. All other implant process steps are run on implanters dedicated entirely to that step. Thus, setups for energy changes are unnecessary at the other implanters. Furthermore, setups for species changes are not needed.

7.6 Pre-Processing and Post-Processing Times

Pre-processing and post-processing times at all single-wafer processing tools are 20 seconds. This time represents preparing the FOUP for the tool. At furnace and wet bench tools, these times are 40 seconds per batch. Furnace and wet bench tools are the only tools with internal buffers. Single wafer tools have only loadports. It is assumed that it takes 20 seconds for a FOUP to be transferred from the loadport to an internal buffer at a batch tool. Then, it takes 20 seconds for the FOUP to be prepared for the tool. In reality, these operations would be performed individually for each FOUP. However, since the pre-processing station performs the batching operation, it must process the entire batch. FOUPs arrive at batch tools one at a time. If each FOUP were pre-processed individually, the first FOUPs would go through the pre-process steps while the last lot was being transported. Thus, the pre-processing time of 40 seconds represents the time to transfer the last FOUP and prepare it for processing. For similar reasons, the post-processing time is also 40 seconds at furnace and wet bench tools.

7.7 Tool Loadport Quantity/Buffer Size

Each tool has a number of loadports and possibly an internal buffer. If the tool has an internal buffer, the loadports are not explicitly modeled. The loadports would not be used for FOUP storage if an internal buffer were present and the pre-processing and post-processing times are extended to represent moving a FOUP between the loadports and internal buffer. Table 5 gives the number of loadports, size of the internal buffer, and modeled buffer size for each tool type.

Table 4 Tool Downtime Parameters

	Failures (exponential distribution)		PM Type 1 (triangular distribution)		PM Type 2 (triangular distribution)	
	MTBF (hrs)	MTTR (hrs)	Time Between PM Parameters (hrs)	Repair Time Parameters (hrs)	Time Between PM Parameters (hrs)	Repair Time Parameters (hrs)
Dry_Strip_D	250	6	23, 24, 25	0.75, 1, 1.25	167, 168, 169	3.5, 4, 4.5
Dry_Strip_I	250	6	23, 24, 25	0.75, 1, 1.25	167, 168, 169	3.5, 4, 4.5
Dry_Strip	250	6	23, 24, 25	0.75, 1, 1.25	167, 168, 169	3.5, 4, 4.5
RTP_OxAn_C	500	4	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
RTP_OxAn	500	4	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
Test	500	6	23, 24, 25	.75, 1, 1.25	167, 168, 169	1.5, 2, 2.5
VP_HF_Clean	500	8	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	3.5, 4, 4.5
Insp_PLY	200	8	23, 24, 25	.75, 1, 1.25	167, 168, 169	1.5, 2, 2.5
Insp_Visual	500	8	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	7.5, 8, 8.5
Meas_CD	500	6	23, 24, 25	.75, 1, 1.25	167, 168, 169	1.5, 2, 2.5
Meas_Film	500	6	23, 24, 25	.75, 1, 1.25	167, 168, 169	3.5, 4, 4.5
Meas_Overlay	500	6	23, 24, 25	.75, 1, 1.25	167, 168, 169	1.5, 2, 2.5
CMP_Ins_C	125	4	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
CMP_Ins_I	125	4	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
CMP_Ins	125	4	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
CMP_Met	125	4	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
CVD_Ins_C	125	6	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
Litho_248	250	6	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	3.5, 4, 4.5
Litho_I	500	6	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	3.5, 4, 4.5
Litho_Iw	250	6	23, 24, 25	.75, 1, 1.25	167, 168, 169	3.5, 4, 4.5
CVD_Ins_I	125	6	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	3.5, 4, 4.5
CVD_Ins	125	6	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
CVD_Ins_Thin	125	6	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	3.5, 4, 4.5
CVD_Met_C	200	8	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
CVD_Met	200	8	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
CVD_MetW_C	200	8	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
CVD_MetW	200	8	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
Dry_Etch_A	250	6	23, 24, 25	1.75, 2, 2.25	167, 168, 169	7.5, 8, 8.5
Dry_Etch_C	250	6	23, 24, 25	1.75, 2, 2.25	167, 168, 169	7.5, 8, 8.5
Dry_Etch_I	250	6	23, 24, 25	2.25, 2.5, 2.75	167, 168, 169	7.5, 8, 8.5
Dry_Etch	250	6	23, 24, 25	1.75, 2, 2.25	167, 168, 169	7.5, 8, 8.5
Dry_Etch_Met	250	6	23, 24, 25	1.75, 2, 2.25	167, 168, 169	7.5, 8, 8.5
PVD_Met_C	125	8	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	3.5, 4, 4.5
PVD_Met	125	8	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	3.5, 4, 4.5
Implant_HiE	125	8	23, 24, 25	1.75, 2, 2.25	167, 168, 169	7.5, 8, 8.5
Implant_LoE	125	8	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	3.5, 4, 4.5
Furn_FastRmp	500	4	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	3.5, 4, 4.5
Furn_Nitr	500	4	23, 24, 25	2.25, 2.5, 2.75	167, 168, 169	7.5, 8, 8.5
Furn_OxAn_I	500	4	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	5.5, 6, 6.5
Furn_Poly	500	4	23, 24, 25	1.75, 2, 2.25	167, 168, 169	7.5, 8, 8.5
Furn_TEOS	500	4	23, 24, 25	1.75, 2, 2.25	167, 168, 169	5.5, 6, 6.5
Wet_Bench_I	500	8	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	3.5, 4, 4.5
Wet_Bench	500	8	23, 24, 25	1.25, 1.5, 1.75	167, 168, 169	3.5, 4, 4.5

Table 5 Number of Loadports and Internal Buffer Size

Tool Type	# of Loadports	Additional Buffer	Model Buffer Input
CMP	2	0	2
CVD	2	0	2
Dry Etch	2	0	2
Dry Strip	3	0	3
Furnace	2	12	12
Implant	4	0	4
Metrology	2	0	2
Lithography	4	0	4
PVD	2	0	2
RTP	2	0	2
Test	2	0	2
Wet Bench	2	10	10
VP Clean	2	10	10

7.8 Tool Batch Size

All furnace and wet bench tools are modeled as batch tools. If there are no hot lots waiting for the batch tool, the following rules take effect: wet benches process batches of two lots while furnaces process batches of between two and four lots. Furnace batches must contain at least two lots. After two lots are available in the stocker, a furnace will wait for up to half of its processing time to see if any more candidate lots arrive. If two more lots arrive (making a total of four lots) within the waiting period, the four lots will form a batch and begin the trip to the tool as soon as the fourth lot is available in the stocker. If the furnace waits for the entire waiting period, then either zero or one more lot has arrived and these two or three lots form a batch and are transported one at a time to the tool.

If there is a hot lot waiting for a batch tool and there are no other lots with the same processing requirements as the hot lot waiting at the stocker for a batch tool, then the hot lot will be processed alone, without waiting for a full batch to be formed. If there is a hot lot at the stocker and there are other lots with the same processing requirements waiting for a batch tool, the hot lot will be batched with the other lots to form a batch.

7.9 Batch Tool Models

Furnace and wet bench tools are modeled as batch tools as described in Sections 4.3.3 and 4.3.4.

7.10 Hot Lots

In the base model, one 25-wafer hot lot is started every 72 hours. This allows hot lots to make up approximately 1% of the total WIP in the system. These lots follow the same process flow as all other lots in the system. They are given priority over all other lots at every process step.

7.11 Non-Product Wafers

Two single-wafer non-product wafers are started every 24 hours. These lots follow the same process flow as all other lots in the system, although at single wafer processing tools where wafers are processed individually, NPWs will have 1/25 the processing time of regular 25-wafer lots. Batch tools batch FOUPs, so, while an NPW lot contains a single wafer, it will take up an entire spot in the batch.

8 RESULTS

The experiments that have been run have consisted of changing the levels of one or more of the detractors or factory options listed above. Experiments were designed to determine the effect of changing the levels of various detractors on factory performance. Experiments include changing the levels of NPWs, AMHS downtimes, and hot lots; changing factory layout to Farm and Modified Hybrid; altering the size of the internal buffers at batch tools; and changing the number of stockers per bay.

A matrix listing which detractors were used at their base level for each experiment is given in Table 6. An entry labeled Base indicates that the detractor was set at its base level in that experiment, while an entry labeled OFF indicates that the detractor was not included in the model during that experiment.

8.1 NPW Experiment

To determine the effect of varying levels of NPW starts on factory productivity, the model was run with different numbers of NPW starts. The model was run with three different NPW levels: one, two, and three single-wafer lot starts per day. All other detractors were at their base model levels. Table 7 and Figure 11 show the results of these runs.

Table 6 Experiment Matrix

Detractor	NPW			AMHS Downtime Experiment	
	1	2	3	4	5
Factory Layout	Hybrid	Hybrid	Hybrid	Hybrid	Hybrid
AMHS Performance	Base	Base	Base	Base	Base
AMHS Downtime (MTBI)	Base	Base	Base	500 hrs	250 hrs
Multiple Products	OFF	OFF	OFF	OFF	OFF
Tool Downtime	Base	Base	Base	Base	Base
Tool Setups	Base	Base	Base	Base	Base
Pre- and Post-Processing Times	Base	Base	Base	Base	Base
Loadport Quantity/Buffer Size	Base	Base	Base	Base	Base
Batch Size	Base	Base	Base	Base	Base
Hot Lots	Base	Base	Base	Base	Base
Non Product Wafers	1/day	2/day	3/day	Base	Base
Multiple Lots in a Pod	OFF	OFF	OFF	OFF	OFF
PGV Intrabay	OFF	OFF	OFF	OFF	OFF
Detractor	**Hot Lots**		**Layout Comparison**		
	6	**7**	**8**	**9**	**10**
Factory Layout	Hybrid	Hybrid	Hybrid	Mod Hybrid	Farm
AMHS Performance	Base	Base	Base	Base	Base
AMHS Downtime (MTBI)	Base	Base	Base	Base	Base
Multiple Products	OFF	OFF	OFF	OFF	OFF
Tool Downtime	Base	Base	Base	Base	Base
Tool Setups	Base	Base	Base	Base	Base
Pre- and Post-Processing Times	Base	Base	Base	Base	Base
Loadport Quantity/Buffer Size	Base	Base	Base	Base	Base
Batch Size	Base	Base	Base	Base	Base
Hot Lots	1/72 hrs	regular lot every 72 hrs	Base	Base	Base
Non Product Wafers	Base	Base	Base	Base	Base
Multiple Lots in a Pod	OFF	OFF	OFF	OFF	OFF
PGV Intrabay	OFF	OFF	OFF	OFF	OFF
Detractor	**# of Stockers**	**Buffer Capacities**			
	13	**14**	**15**	**16**	**17**
Factory Layout	Hybrid	Hybrid	Hybrid	Hybrid	Hybrid
AMHS Performance	2 stockers/bay	Base	Base	Base	Base
AMHS Downtime (MTBI)	Base	Base	Base	Base	Base
Multiple Products	OFF	OFF	OFF	OFF	OFF
Tool Downtime	Base	Base	Base	Base	Base
Tool Setups	Base	Base	Base	Base	Base
Pre- and Post-Processing Times	Base	Base	Base	Base	Base
Loadport Quantity/Buffer Size	Base	Wet Bench: 8 Furnace 10	Wet Bench: 6 Furnace 8	Wet Bench: 4 Furnace 6	Wet Bench: 2 Furnace 4
Batch Size	Base	Base	Base	Base	Base
Hot Lots	Base	Base	Base	Base	Base
Non Product Wafers	Base	Base	Base	Base	Base
Multiple Lots in a Pod	OFF	OFF	OFF	OFF	OFF
PGV Intrabay	OFF	OFF	OFF	OFF	OFF

Table 7 NPW Experiment Results

		1 NPW lot per day	2 NPW lots per day	3 NPW lots per day
Length of one replication		900 Days	900 Days	900 Days
# of replications		5	5	5
Tool Count		277 Tools	277 Tools	277 Tools
Cycle Time	Average	20.7 Days	21.0 Days	21.3 Days
	Std. Dev.	5.1 Hours	4.4 Hours	4 Hours
	95% Conf. Interval	(20.6,20.9) days	(20.8,21.1) days	(21.1, 21.4) days
Factory WIP Level	Average	587.6 FOUPs	613.9 FOUPs	645.6 FOUPs
	Std. Dev.	6.0 FOUPs	5.3 FOUPs	5.1 FOUPs
	95% Conf. Interval	(582.3,592.9) FOUPs	(609.3,618.5) FOUPs	(641.1,650.0) FOUPs
Regular Lot Cycle Time	Average	21.0 Days	21.4 Days	21.9 Days
	Std. Dev.	5.1 Hours	4.5 Hours	4.1 Hours
	95% Conf. Interval	(20.8,21.2) days	(21.2,21.5) days	(21.7,22.0) days
Regular Lot WIP Level	Average	566.9 FOUPs	577.2 FOUPs	590.0 FOUPs
	Std. Dev.	5.8 FOUPs	5.0 FOUPs	4.6 FOUPs
	95% Conf. Interval	(561.8,572.0) FOUPs	(572.8,581.6) FOUPs	(586.0,594.0) FOUPs
Hot Lot Cycle Time	Average	14.0 Days	14.0 Days	14.2 Days
	Std. Dev.	1.6 Hours	1.8 Hours	1.9 Hours
	95% Conf. Interval	(14.0,14.1) days	(14.0,14.1) days	(14.2,14.3) days
Hot Lot WIP Level	Average	4.7 FOUPs	4.7 FOUPs	4.7 FOUPs
	Std. Dev.	0.02 FOUPs	0.03 FOUPs	0.03 FOUPs
	95% Conf. Interval	(4.66,4.69) FOUPs	(4.66,4.70) FOUPs	(4.7,4.8) FOUPs
NPW Cycle Time	Average	16.0 Days	16.5 Days	16.9 Days
	Std. Dev.	5.0 Hours	3.8 Hours	3.9 Hours
	95% Conf. Interval	(15.8,16.2) days	(16.3,16.6) days	(16.8,17.1) days
NPW WIP Level	Average	16.0 FOUPs	33.0 FOUPs	50.8 FOUPs
	Std. Dev.	0.2 FOUPs	0.3 FOUPs	0.5 FOUPs
	95% Conf. Interval	(15.8,16.2) FOUPs	(32.7,33.3) FOUPs	(50.3,51.3) FOUPs
Factory Average OEE		64%	66%	66%

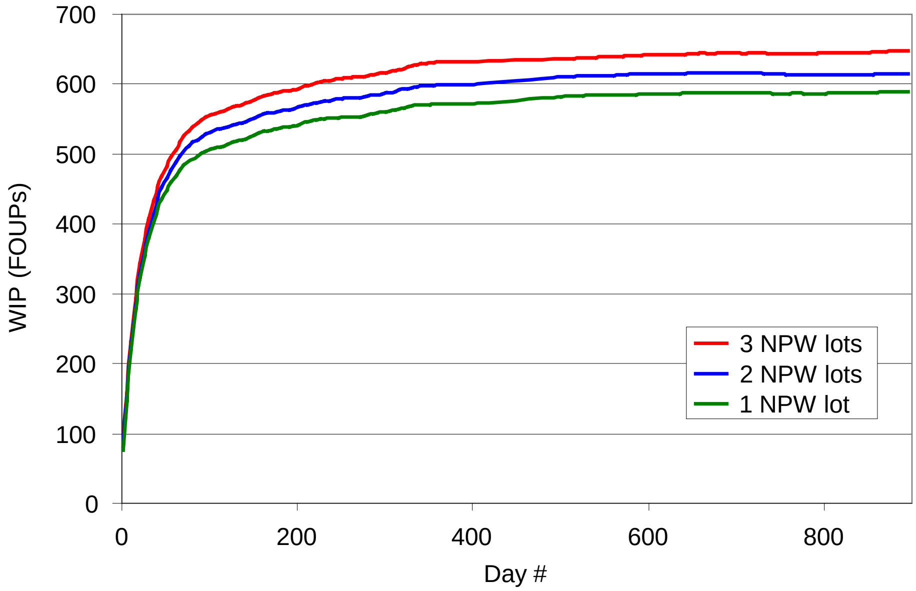


Figure 11 NPW Experiment WIP Evolution

When this experiment was originally performed, the model with three NPW starts per day was unstable. That is, the WIP in the factory continued to grow without ever reaching a point where it leveled off. In the experiment presented here, it is stable. The problem in the original experiment was with the interbay transport system. At each end of the factory, the interbay vehicles have to slow down to round a curve in order to change direction. The vehicles can stop only at specific points along the track; such points were on either side of the curve. For two vehicles to go around the curve, the second vehicle would have to wait for the first to completely round the curve and reach the point on the other side. In addition, any other vehicles waiting to go around the curve would stack up at the access points to stockers, blocking access to these stockers. There was almost always a line of several vehicles waiting to go around the curve, effectively slowing down delivery times. The effect of this was that the interbay system could not handle the additional loading caused by three NPWs per day. In the base model now in use as well as the models used in this experiment, there are five points around the curve and three points on either side of the curve at which vehicles can stop. Figure 12 shows one of the interbay curves. The additional points are all to the right of the solid red line. The two stopping points that were included in the original model are marked with arrows. Vehicles now must wait only for the vehicle in front of them to go about a quarter of the way around the curve before they can start moving again. Vehicles waiting for other vehicles to go around the curve do not necessarily have to block access to stockers as there are now several additional stopping points on either side of the bay. There is no longer a line in front of each curve on the interbay system, so vehicles are not slowed down by congestion at the curves. As a result, the interbay transport system can handle the additional loading caused by three NPWs a day. To show the effect of the extra points, the model with three NPW lot starts a day was run without the additional points. All other parameters were at their base levels. The evolution of the WIP in this model is shown in Figure 13.

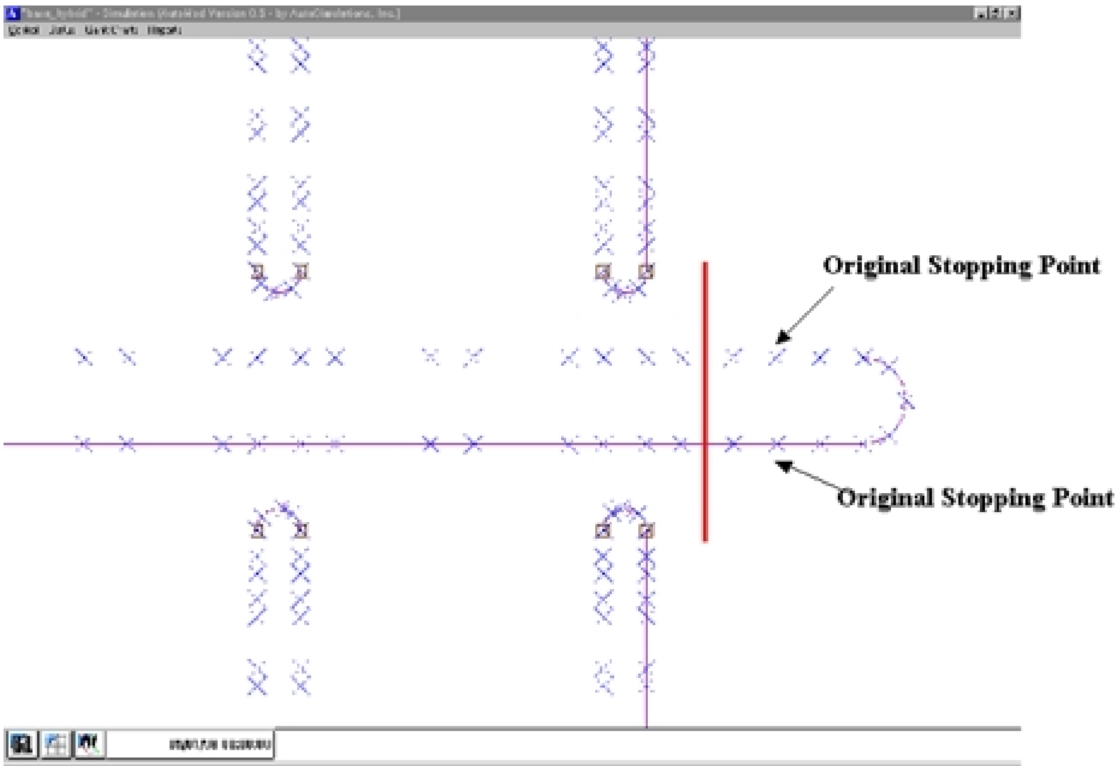


Figure 12 Interbay System with Additional Stopping Points

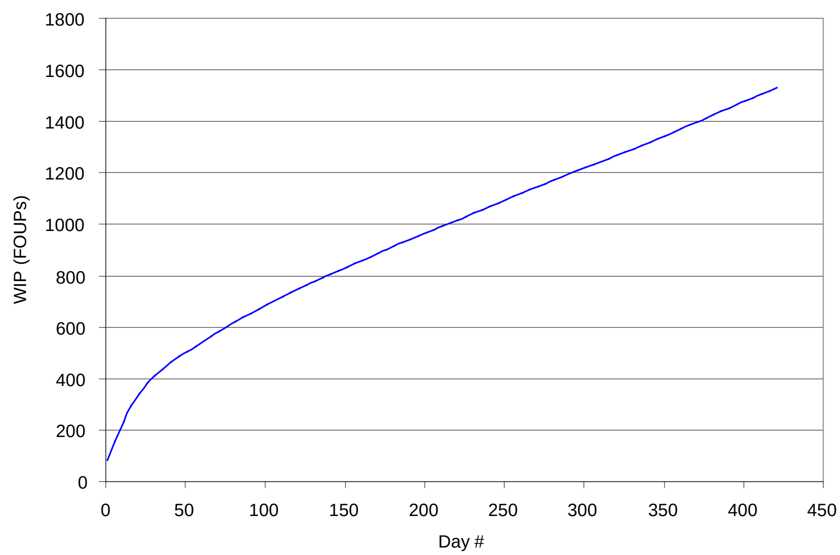


Figure 13 WIP Evolution with Three NPW Starts Per Day and No Additional Stopping Points

The model is unable to reach steady state as the WIP continues to increase. Thus, the additional stopping points provide the extra capacity on the interbay system to allow the factory to handle the additional loading of an extra wafer start every day. In fact, the factory can now handle an additional 25-wafer lot every day. To demonstrate the effects of the extra stopping points on the interbay system, a model with these extra points taken out was run. Three NPW lots are started every day in this model. All other parameters are at their base levels. This model did not reach steady state. Figure 14 shows a snapshot of one end of the interbay system. The model had been running for several hundred days. There is one vehicle traveling on the curve and 14 vehicles delayed in front of the curve.

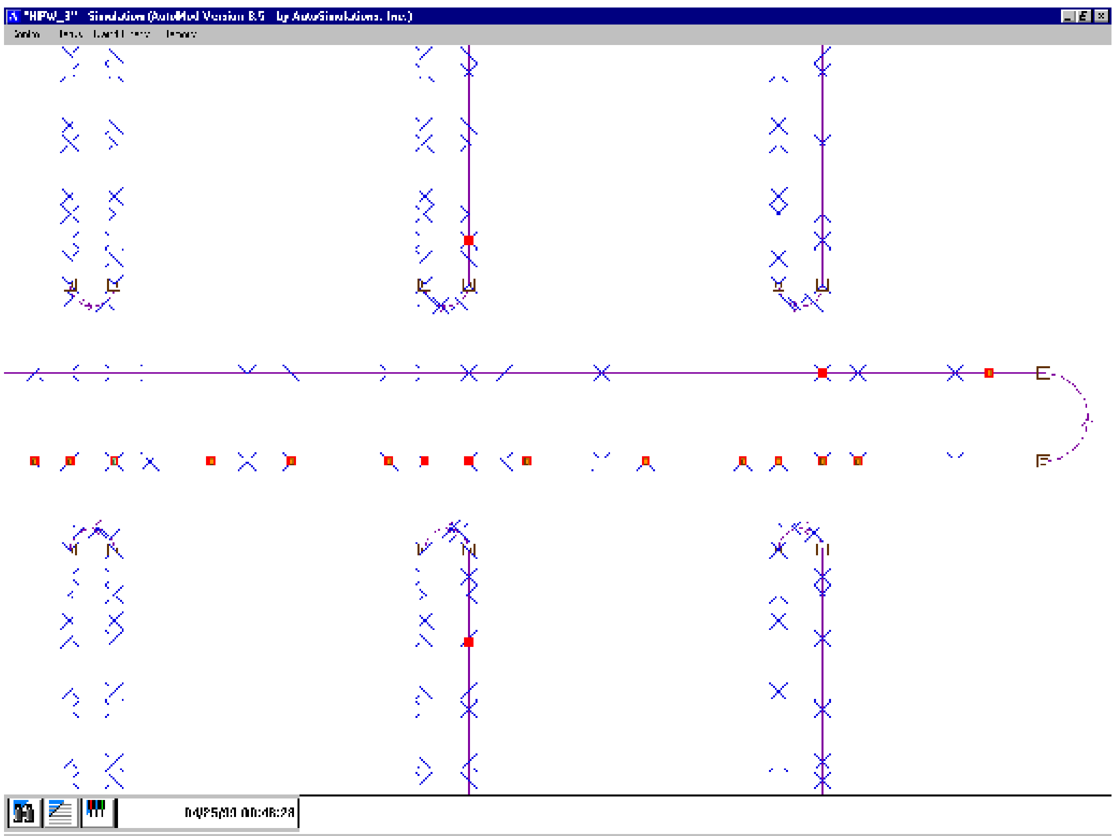


Figure 14 Three NPW Starts per Day and No Additional Stopping Points

To test the robustness of the factory with respect to the number of wafer starts per day, another model was designed. This model had the base level of nine regular lots started every eight hours, two single-wafer NPW lots started every day, one 25-wafer hot lot started every three days. In addition, another 25-wafer regular lot was started every day. The interbay system in this model had all the additional stopping points included. The WIP evolution for this model shown in Figure 15 shows the average WIP in the factory leveling off at a level of about 665 FOUPs. Thus, the factory can handle the additional loading of starting 25 extra wafers in a single FOUP every day.

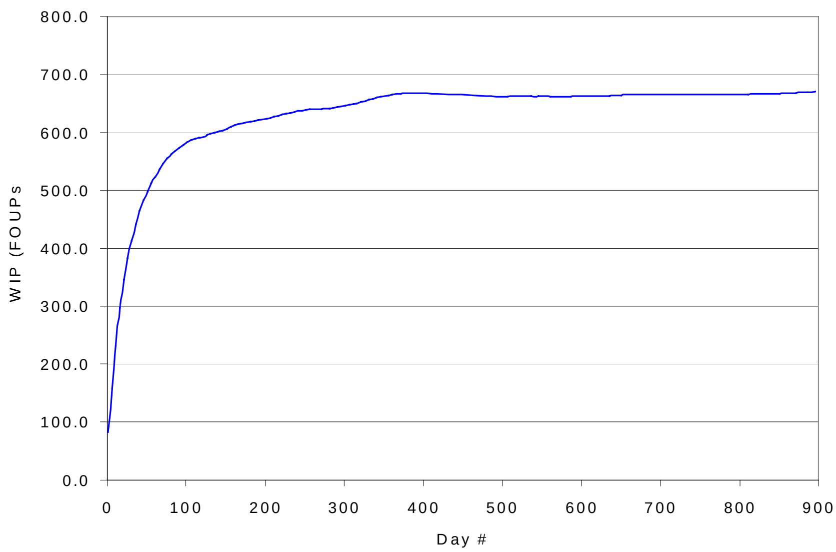


Figure 15 WIP Evolution with an Extra Lot Start Every Day

8.2 AMHS Downtime Experiment

To determine the effect of different levels of AMHS downtime, the model was run in two configurations. In the first, all vehicles and stockers fail with a MTBI of 500 hours. In the second, the MTBI is 250 hours for all vehicles and stockers. Each of these models was replicated five times according to the replication plan presented in Section 6. Figure 16 and Figure 17 graphically show the results of the replications of the models with MTBI of 500 hours and 250 hours respectively. The figures show that the replications do not differ significantly from each other.

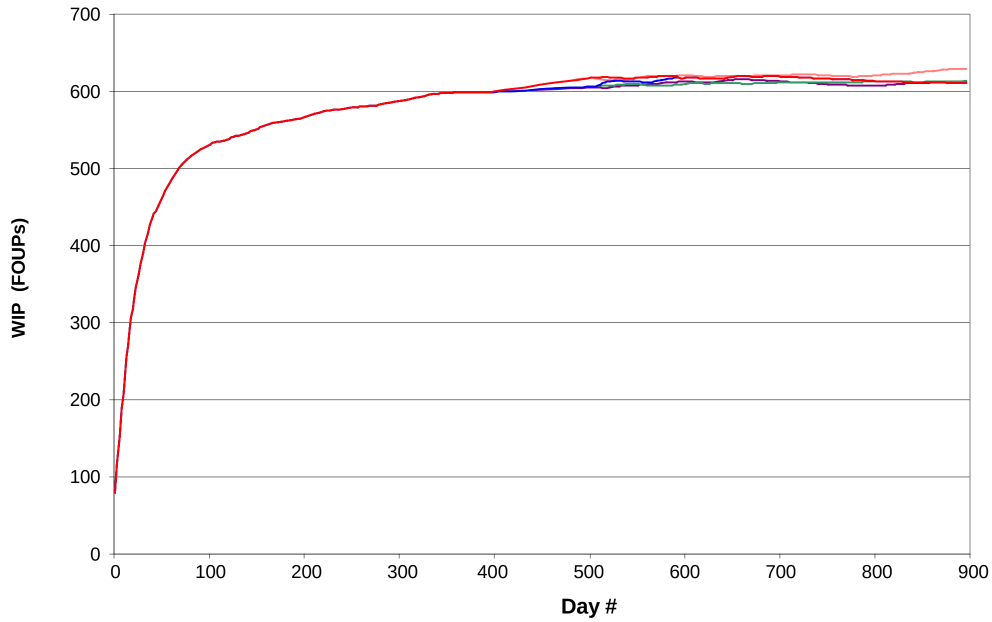


Figure 16 AMHS Downtime Experiment WIP Evolution for MTBI = 500 hours

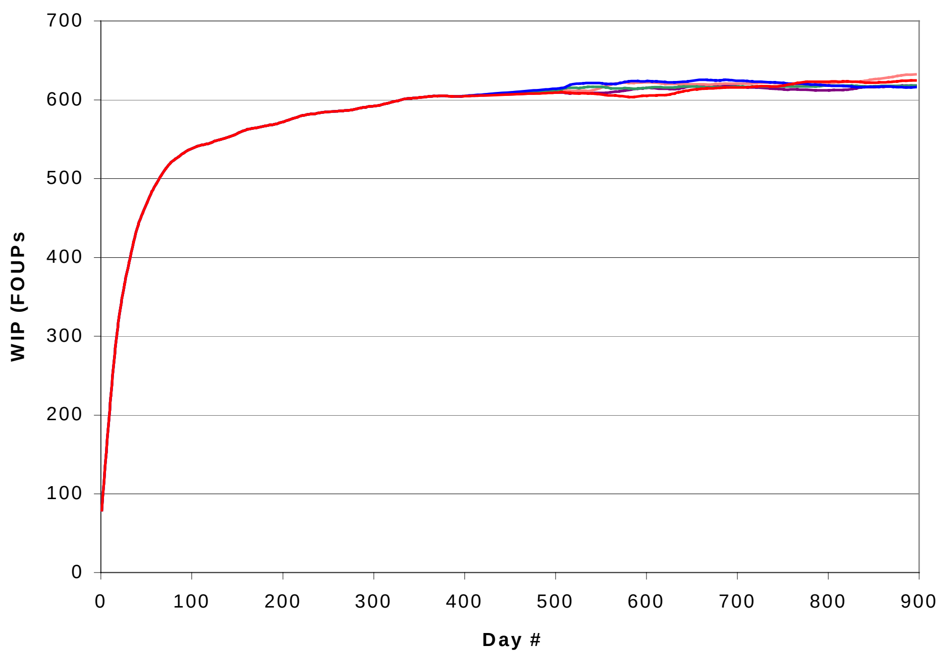


Figure 17 AMHS Downtime Experiment WIP Evolution for MTBI = 250 hours

Table 8 shows the results of the experiment. The Hybrid layout with the base level of 273 tools was used. For each of the two experiments, the cycle time for each replication was averaged, the standard deviation over the set of replications was found, and a 95% confidence interval for the average cycle time was calculated. The same values were calculated for the WIP inventory. The average factory tool utilization and the idle time percentage for the tools are also given.

Table 8 AMHS Downtime Experiment Results

		MTBF = 500 hrs	MTBF = 250 hrs
Length of one replication		900 Days	900 Days
# of replications		5	5
Tool Count		277 Tools	277 Tools
Cycle Time	Average	21.0 Days	21.1 Days
	Std. Dev.	4.4 Hours	3.2 Hours
	95% Confidence Interval	(20.8,21.1) days	(21.0,21.2) days
Factory WIP Level	Average	613.9 FOUPs	619.6 FOUPs
	Std. Dev.	5.3 FOUPs	4.0 FOUPs
	95% Confidence Interval	(609.3,618.5) FOUPs	(616.1,623.0) FOUPs
Regular Lot Cycle Time	Average	21.4 Days	21.5 Days
	Std. Dev.	4.5 Hours	3.2 Hours
	95% Confidence Interval	(21.2,21.5) days	(21.4,21.7) days
Regular Lot WIP Level	Average	577.2 FOUPs	581.6 FOUPs
	Std. Dev.	5.0 FOUPs	3.7 FOUPs
	95% Confidence Interval	(572.8,581.6) FOUPs	(578.4,584.8) FOUPs
Hot Lot Cycle Time	Average	14.0 Days	14.1 Days
	Std. Dev.	1.8 Hours	1.9 Hours
	95% Confidence Interval	(14.0,14.1) days	(14.1,14.2) days
Hot Lot WIP Level	Average	4.7 FOUPs	4.7 FOUPs
	Std. Dev.	0.03 FOUPs	0.03 FOUPs
	95% Confidence Interval	(4.66,4.70) FOUPs	(4.69,4.74) FOUPs
NPW Cycle Time	Average	16.5 Days	16.6 Days
	Std. Dev.	3.8 Hours	3.2 Hours
	95% Confidence Interval	(16.3,16.6) days	(16.5,16.7) days
NPW WIP Level	Average	33.0 FOUPs	33.2 FOUPs
	Std. Dev.	0.3 FOUPs	0.3 FOUPs
	95% Confidence Interval	(32.7,33.3) FOUPs	(33.0,33.5) FOUPs
Factory average OEE		66%	66%

Figure 18 compares the evolution of WIP for the two models. The average WIP for the model with MTBI = 250 hours is slightly greater than that of the model with MTBI = 500 hours. The difference is not as great as was expected. Further experiments are tentatively planned to determine the effect of even more frequent failures.

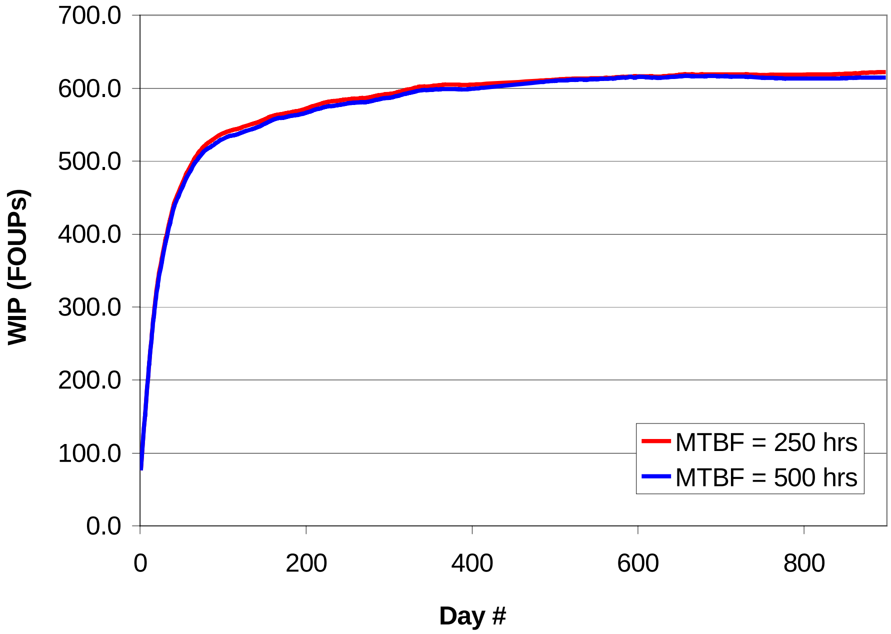


Figure 18 AMHS Downtime Experiment WIP Evolution Comparison

8.3 Hot Lot Experiment

To test the effect of hot lots on the system, two models were developed. The first is the base model with a single 25-wafer hot lot start every 72 hours. In the second, the hot lot start was converted to a regular lot start. Thus, in addition to the nine regular lot starts every eight hours and the two single-wafer NPW lot starts every day, another lot was started every 72 hours, but this lot was not given any priority over other lots in the system. Each of these models was run for five replications. Table 9 and Figure 19 show the results of this experiment.

Table 9 Hot Lot Experiment Results

		Hot Lot	Regular Lot
Length of one replication		900 Days	900 Days
Number of replications		5	5
Tool Count		277 Tools	277 Tools
Cycle Time	Average	21.0 Days	20.9 Days
	Standard Deviation	4.4 Hours	4.4 Hours
	95% Confidence Interval	(20.8,21.1) days	(20.7,21.1) days
Factory WIP Level	Average	613.9 FOUPs	613.2 FOUPs
	Standard Deviation	5.3 FOUPs	5.4 FOUPs
	95% Confidence Interval	(609.3,618.5) FOUPs	(608.5,617.9) FOUPs
Regular Lot Cycle Time	Average	21.4 Days	21.2 Days
	Standard Deviation	4.5 Hours	4.3 Hours
	95% Confidence Interval	(21.2,21.5) days	(21.1,21.4) days
Regular Lot WIP Level	Average	577.2 FOUPs	580.5 FOUPs
	Standard Deviation	5.0 FOUPs	5.0 FOUPs
	95% Confidence Interval	(572.8,581.6) FOUPs	(575.8,584.5) FOUPs
Hot Lot Cycle Time	Average	14.0 Days	N/A
	Standard Deviation	1.8 Hours	N/A
	95% Confidence Interval	(14.0,14.1) days	N/A
Hot Lot WIP Level	Average	4.7 FOUPs	N/A
	Standard Deviation	0.03 FOUPs	N/A
	95% Confidence Interval	(4.66,4.70) FOUPs	N/A
NPW Cycle Time	Average	16.5 Days	16.5 Days
	Standard Deviation	3.8 Hours	4.8 Hours
	95% Confidence Interval	(16.3,16.6) days	(16.3,16.7) days
NPW WIP Level	Average	33.0 FOUPs	33.0 FOUPs
	Standard Deviation	0.3 FOUPs	0.4 FOUPs
	95% Confidence Interval	(32.7,33.3) FOUPs	(32.7,33.4) FOUPs
Factory Average OEE		66%	66%

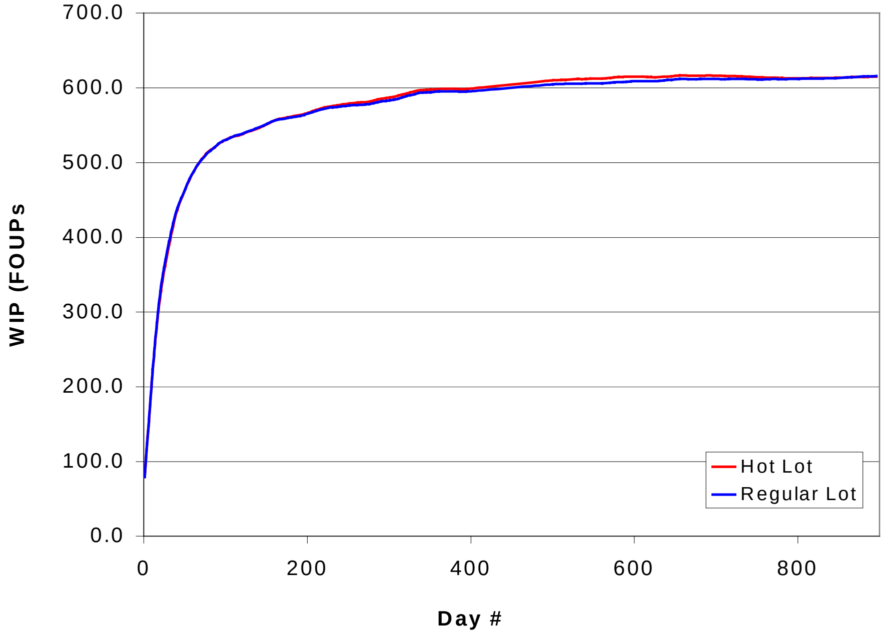


Figure 19 Hot Lot Experiment WIP Evolution Comparison

Examination of the confidence intervals for the average WIP and cycle time for each type of wafer in each model shows no conclusive difference between the two models. Thus, a small number of hot lots do not adversely affect the performance of the factory.

8.4 Layout Comparison Experiment

Three layout configurations were developed during Phase I of this project. While most of the experiments discussed in this report focus on the Hybrid layout, a comparison with the Modified Hybrid and Farm layouts was also desired. The performance of the base model, with the Hybrid layout, was compared to the performance of models with the Modified Hybrid and Farm layouts. The three layouts are described in Section 4.1. For a more detailed discussion of the factory layouts developed during Phase I of this project, see *300 mm Factory Layout and Material Handling Modeling: Phase I Report*.

Table 10 and Figure 20 compare the results of the models with each of the three layouts. All other parameters were set to their base levels. Each model was run for five replications.

Table 10 Layout Comparison Experiment Results

		Hybrid	Modified Hybrid	Farm
Length of one replication		900 Days	900 Days	900 Days
Number of replications		5	5	5
Tool Count		277 Tools	287 Tools	277 Tools
Cycle Time	Average	21.0 Days	20.6 Days	21.5 Days
	Standard Deviation	4.4 Hours	5.6 Hours	5.2 Hours
	95% Confidence Interval	(20.8,21.1) days	(20.4,20.8) days	(21.3, 21.7) days
Factory WIP Level	Average	613.9 FOUPs	603.5 FOUPs	631.7 FOUPs
	Standard Deviation	5.3 FOUPs	6.9 FOUPs	6.4 FOUPs
	95% Confidence Interval	(609.3,618.5) FOUPs	(597.4,609.5) FOUPs	(626.1,637.3) FOUPs
Regular Lot Cycle Time	Average	21.4 Days	21.0 Days	22.0 Days
	Standard Deviation	4.5 Hours	5.7 Hours	5.3 Hours
	95% Confidence Interval	(21.2,21.5) days	(20.8,21.2) days	(21.8,22.2) days
Regular Lot WIP Level	Average	577.2 FOUPs	566.6 FOUPs	593.3 FOUPs
	Standard Deviation	5.0 FOUPs	6.4 FOUPs	6.0 FOUPs
	95% Confidence Interval	(572.8,581.6) FOUPs	(561.0,572.2) FOUPs	(588.0,598.5) FOUPs
Hot Lot Cycle Time	Average	14.0 Days	14.2 Days	14.5 Days
	Standard Deviation	1.8 Hours	1.9 Hours	1.1 Hours
	95% Confidence Interval	(14.0,14.1) days	(14.1,14.3) days	(14.5,14.6) days
Hot Lot WIP Level	Average	4.7 FOUPs	4.7 FOUPs	4.8 FOUPs
	Standard Deviation	0.03 FOUPs	0.03 FOUPs	0.02 FOUPs
	95% Confidence Interval	(4.66,4.70) FOUPs	(4.71,4.76) FOUPs	(4.83,4.86) FOUPs
NPW Cycle Time	Average	16.5 Days	16.1 Days	16.8 Days
	Standard Deviation	3.8 Hours	5.4 Hours	5.1 Hours
	95% Confidence Interval	(16.3,16.6) days	(15.9,16.3) days	(16.6,17.0) days
NPW WIP Level	Average	33.0 FOUPs	32.1 FOUPs	33.6 FOUPs
	Standard Deviation	0.3 FOUPs	0.5 FOUPs	0.4 FOUPs
	95% Confidence Interval	(32.7,33.3) FOUPs	(31.7,32.5) FOUPs	(33.2,34.0) FOUPs
Factory average OEE		66%	64%	66%

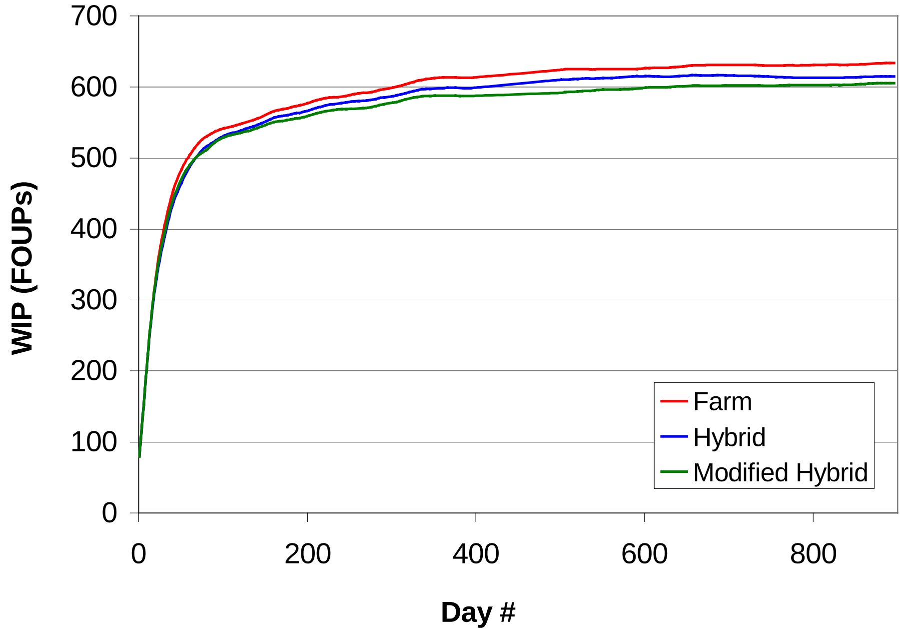


Figure 20 Layout Comparison Experiment WIP Evolution

The Farm layout results in the highest average WIP and cycle time, while the Modified Hybrid results in the lowest WIP and cycle time.

8.5 Stocker Experiment

Each bay in the base model has one stocker. In the original vision of the base model, there were to be two stockers in each bay. One of these stockers was to be used by FOUPs arriving at the bay and those FOUPs that would possibly be sent to another tool in the same bay as their previous step. The second stocker was to be used by FOUPs that had completed processing within a bay and would definitely be sent to a tool in another bay because no tools appropriate for the next processing step are present in the current bay. FOUPs being rerouted due to a stocker failure could use both types of stockers. The experiment discussed here was designed to compare the use of one versus two stockers in each bay.

The results of this experiment and the evolution of WIP for this experiment can be seen in Table 11 and Figure 21. Because the first stocker in each bay is used in more situations, in all experiment results, the first stocker in each bay is utilized more than the second stocker.

Table 11 Stocker Experiment Results

		One Stocker Per Bay	Two Stockers Per Bay
Length of one replication		900 Days	900 Days
Number of replications		5	5
Tool Count		277 Tools	277 Tools
Cycle Time	Average	21.0 Days	20.9 Days
	Standard Deviation	4.4 Hours	2.8 Hours
	95% Confidence Interval	(20.8,21.1) days	(20.8,21.0) days
Factory WIP Level	Average	613.9 FOUPs	613.2 FOUPs
	Standard Deviation	5.3 FOUPs	3.5 FOUPs
	95% Confidence Interval	(609.3,618.5) FOUPs	(610.1,616.3) FOUPs
Regular Lot Cycle Time	Average	21.4 Days	21.3 Days
	Standard Deviation	4.5 Hours	2.9 Hours
	95% Confidence Interval	(21.2,21.5) days	(21.2,21.4) days
Regular Lot WIP Level	Average	577.2 FOUPs	575.8 FOUPs
	Standard Deviation	5.0 FOUPs	3.4 FOUPs
	95% Confidence Interval	(572.8,581.6) FOUPs	(572.9,578.8) FOUPs
Hot Lot Cycle Time	Average	14.0 Days	14.1 Days
	Standard Deviation	1.8 Hours	1.7 Hours
	95% Confidence Interval	(14.0,14.1) days	(14.0,14.1) days
Hot Lot WIP Level	Average	4.7 FOUPs	4.7 FOUPs
	Standard Deviation	0.03 FOUPs	0.02 FOUPs
	95% Confidence Interval	(4.66,4.70) FOUPs	(4.67,4.71) FOUPs
NPW Cycle Time	Average	16.5 Days	16.4 Days
	Standard Deviation	3.8 Hours	2.2 Hours
	95% Confidence Interval	(16.3,16.6) days	(16.3,16.4) days
NPW WIP Level	Average	33.0 FOUPs	32.7 FOUPs
	Standard Deviation	0.3 FOUPs	0.2 FOUPs
	95% Confidence Interval	(32.7,33.3) FOUPs	(32.6,32.9) FOUPs
Factory Average OEE		66%	66%

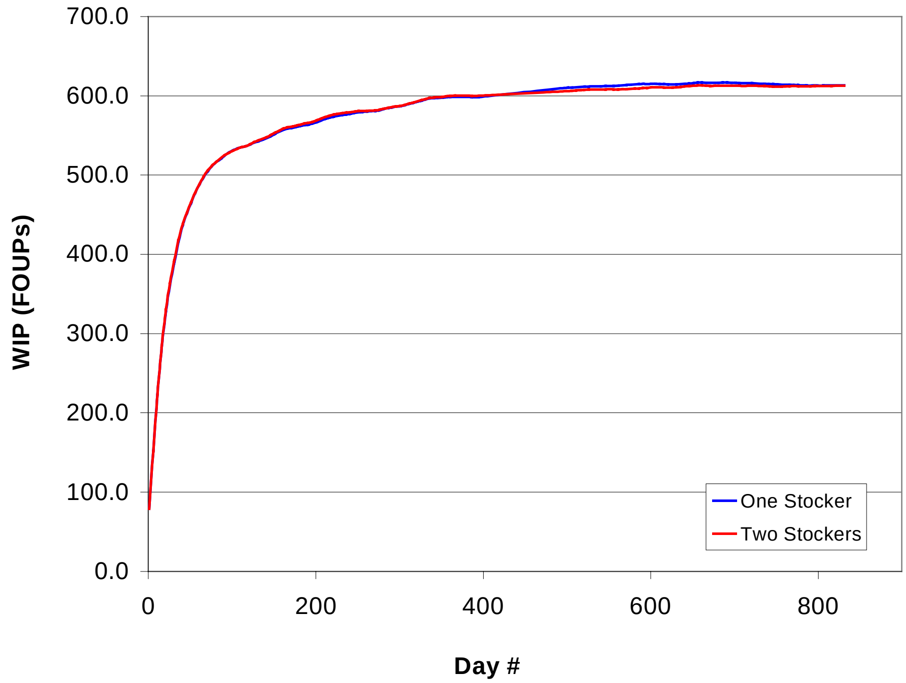


Figure 21 Stocker Experiment WIP Evolution

Examination of the results of this experiment show that the tools and vehicles perform as in other experiments. Table 12 and Table 13 provide the results for the stockers in the single-stocker and two-stocker models, respectively.

Table 12 Single-Stocker Experiment Stocker Statistics

Functional Area	Stocker	Avg. WIP	Max. WIP	Robot Util.	I/O Port Util. Inter In Util.	I/O Port Util. Inter Out Util.	Intra In Util.	Intra Out Util.
Implant	Ast1_stor	16.7	153	0.16	0.03	0.11	0.10	0.30
CMP	Bst1_stor	15.1	85	0.34	0.09	0.26	0.19	0.45
Photolithography	Cst1_stor	3.7	44	0.37	0.10	0.28	0.21	0.49
CMP	Dst1_stor	7.2	83	0.26	0.06	0.19	0.15	0.36
Photolithography	Est1_stor	4.9	70	0.40	0.10	0.29	0.23	0.53
Wet Area BEOL	Fst1_stor	9.7	45	0.42	0.12	0.34	0.23	0.55
Photolithography	Gst1_stor	1.2	26	0.25	0.04	0.14	0.16	0.35
Wet Area BEOL	Hst1_stor	10.5	100	0.42	0.13	0.35	0.22	0.52
Photolithography	Ist1_stor	7.3	74	0.46	0.13	0.34	0.26	0.79
Wet Area FEOL	Jst1_stor	11.3	40	0.41	0.09	0.27	0.26	0.59
Etch & Strip FEOL	Kst1_stor	3.6	85	0.13	0.03	0.10	0.07	0.20
Furnace & RTP	Lst1_stor	9.6	56	0.26	0.06	0.20	0.14	0.36
Etch & Strip FEOL	Mst1_stor	2.8	91	0.21	0.06	0.18	0.11	0.33
Furnace & RTP	Nst1_stor	16.0	101	0.25	0.07	0.21	0.13	0.30
Etch & Strip BEOL	Ost1_stor	1.0	62	0.17	0.05	0.15	0.08	0.24
Metal Dep.	Pst1_stor	1.7	78	0.12	0.03	0.11	0.06	0.17
Etch & Strip BEOL	Qst1_stor	0.9	38	0.12	0.03	0.11	0.06	0.18
Metal Dep.	Rst1_stor	2.5	105	0.15	0.03	0.10	0.10	0.32
Etch & Strip BEOL	Sst1_stor	1.7	72	0.10	0.03	0.10	0.05	0.18
Metal Dep.	Tst1_stor	1.8	62	0.06	0.01	0.04	0.04	0.15
Test	Ust1_stor	0.8	37	0.14	0.04	0.11	0.07	0.24
CVD BEOL	Vst1_stor	2.4	38	0.26	0.06	0.20	0.14	0.35
CVD BEOL	Xst1_stor	14.0	136	0.23	0.06	0.18	0.12	0.37

Table 13 Two-Stocker Experiment Stocker Statistics

Functional Area	Stocker	Avg. WIP	Max. WIP	Robot Util.	I/O Port Util. Inter In Util.	I/O Port Util. Inter Out Util.	Intra In Util.	Intra Out Util.
Implant	Ast1_stor	16.4	159	0.10	0.03	0.00	0.04	0.30
CMP	Bst1_stor	15.0	86	0.30	0.09	0.21	0.15	0.45
Photolithography	Cst1_stor	3.6	51	0.37	0.10	0.28	0.21	0.49
CMP	Dst1_stor	7.2	69	0.25	0.06	0.17	0.14	0.36
Photolithography	Est1_stor	4.9	62	0.40	0.10	0.29	0.23	0.53
Wet Area BEOL	Fst1_stor	9.3	43	0.34	0.11	0.21	0.15	0.55
Photolithography	Gst1_stor	1.1	30	0.20	0.04	0.06	0.12	0.35
Wet Area BEOL	Hst1_stor	10.5	92	0.41	0.13	0.34	0.20	0.52
Photolithography	Ist1_stor	7.2	70	0.46	0.13	0.34	0.26	0.79
Wet Area FEOL	Jst1_stor	10.6	45	0.28	0.08	0.05	0.12	0.58
Etch & Strip FEOL	Kst1_stor	3.4	97	0.10	0.03	0.03	0.04	0.20
Furnace & RTP	Lst1_stor	9.4	65	0.23	0.06	0.15	0.11	0.36

Functional Area	Stocker	Avg. WIP	Max. WIP	Robot Util.	I/O Port Util.		Intra In Util.	Intra Out Util.
					Inter In Util.	Inter Out Util.		
Etch & Strip FEOL	Mst1_stor	2.4	95	0.11	0.05	0.00	0.01	0.34
Furnace & RTP	Nst1_stor	15.5	96	0.16	0.06	0.05	0.03	0.29
Etch & Strip BEOL	Ost1_stor	0.7	57	0.09	0.04	0.00	0.00	0.25
Metal Dep.	Pst1_stor	1.5	72	0.06	0.03	0.00	0.00	0.18
Etch & Strip BEOL	Qst1_stor	0.7	51	0.06	0.03	0.00	0.00	0.18
Metal Dep.	Rst1_stor	2.4	117	0.10	0.03	0.00	0.05	0.33
Etch & Strip BEOL	Sst1_stor	1.6	64	0.07	0.03	0.04	0.02	0.18
Metal Dep.	Tst1_stor	1.8	48	0.05	0.01	0.02	0.03	0.15
Test	Ust1_stor	0.6	34	0.07	0.04	0.00	0.00	0.25
CVD BEOL	Vst1_stor	2.3	34	0.25	0.06	0.19	0.13	0.35
CVD BEOL	Xst1_stor	13.8	128	0.18	0.05	0.09	0.07	0.38
Implant	Ast2_stor	0.2	15	0.06	0.00	0.12	0.06	0.00
CMP	Bst2_stor	0.1	12	0.03	0.00	0.06	0.03	0.00
Photolithography	Cst2_stor	0.0	17	0.00	0.00	0.00	0.00	0.00
CMP	Dst2_stor	0.0	10	0.01	0.00	0.02	0.01	0.00
Photolithography	Est2_stor	0.0	17	0.00	0.00	0.00	0.00	0.00
Wet Area BEOL	Fst2_stor	0.3	14	0.07	0.00	0.14	0.07	0.00
Photolithography	Gst2_stor	0.2	12	0.04	0.00	0.09	0.04	0.00
Wet Area BEOL	Hst2_stor	0.1	17	0.01	0.00	0.02	0.01	0.00
Photolithography	Ist2_stor	0.0	19	0.00	0.00	0.00	0.00	0.00
Wet Area FEOL	Jst2_stor	0.5	22	0.13	0.00	0.23	0.13	0.00
Etch & Strip FEOL	Kst2_stor	0.1	7	0.03	0.00	0.07	0.03	0.00
Furnace & RTP	Lst2_stor	0.1	20	0.03	0.00	0.06	0.03	0.00
Etch & Strip FEOL	Mst2_stor	0.4	14	0.10	0.00	0.18	0.09	0.00
Furnace & RTP	Nst2_stor	0.4	29	0.09	0.00	0.16	0.09	0.00
Etch & Strip BEOL	Ost2_stor	0.3	14	0.08	0.00	0.15	0.08	0.00
Metal Dep.	Pst2_stor	0.2	10	0.06	0.00	0.12	0.06	0.00
Etch & Strip BEOL	Qst2_stor	0.2	12	0.06	0.00	0.12	0.06	0.00
Metal Dep.	Rst2_stor	0.2	10	0.05	0.00	0.10	0.05	0.00
Etch & Strip BEOL	Sst2_stor	0.1	7	0.03	0.00	0.06	0.03	0.00
Metal Dep.	Tst2_stor	0.0	5	0.01	0.00	0.02	0.01	0.00
Test	Ust2_stor	0.2	16	0.07	0.00	0.11	0.07	0.00
CVD BEOL	Vst2_stor	0.0	14	0.01	0.00	0.02	0.01	0.00
CVD BEOL	Xst2_stor	0.2	11	0.05	0.00	0.10	0.05	0.00

The performance in each stocker in the base model is very similar to the performance of the corresponding in-stocker in the two-stocker model. The out-stocker in the two-stocker model is not utilized very much, which explains why eliminating a stocker in each bay does not cause a significant difference in factory performance.

8.6 Buffer Experiment

In the base model, each furnace and wet bench has its own internal buffer to hold lots waiting for processing as well as the empty FOUPs for the lots currently being processed. Wet benches have buffers with space for 10 FOUPs and furnaces have buffers for 12 FOUPs. Wet benches process two lots in each batch and have four baths. Thus, the buffer can hold up to eight empty FOUPs for the lots in the baths and another batch of two lots waiting for the first bath to become empty. Furnaces batch between two and four lots. If a furnace is processing complete batches of four lots, the buffer can hold four FOUPs for the batch currently in the furnace, four more FOUPs for a batch currently cooling down, and four more lots waiting for processing at the furnace.

To test the sensitivity of factory performance to the size of the internal buffers at the batch tools, five models with varying buffer sizes were run. The first model has the base buffer sizes of 10 for wet benches and 12 for furnaces. In each of the subsequent models, the size of each buffer was decreased by the minimum batch size, two. Due to time constraints, these experiments were not replicated.

Figure 22 shows the WIP evolution for each of the models. The model with wet bench buffer sizes of two and furnace buffer sizes of four never reached steady state. To make the results of the other four models more readable, the unstable line was cut short in Figure 22. Figure 23 shows the complete graph for the model with buffer sizes of two and four for the wet benches and furnaces, respectively.

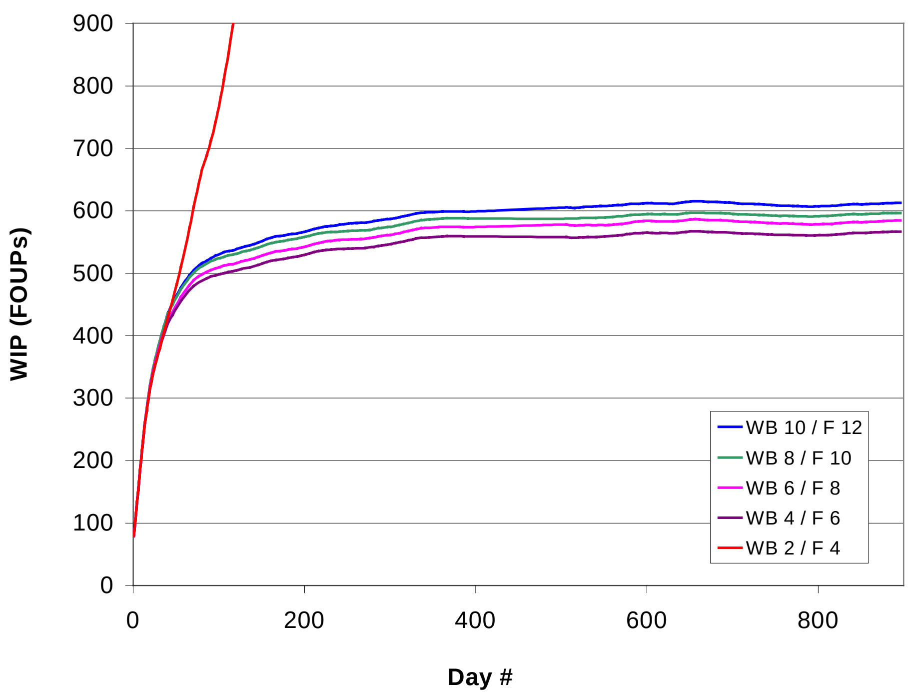


Figure 22 Buffer Experiment WIP Evolution

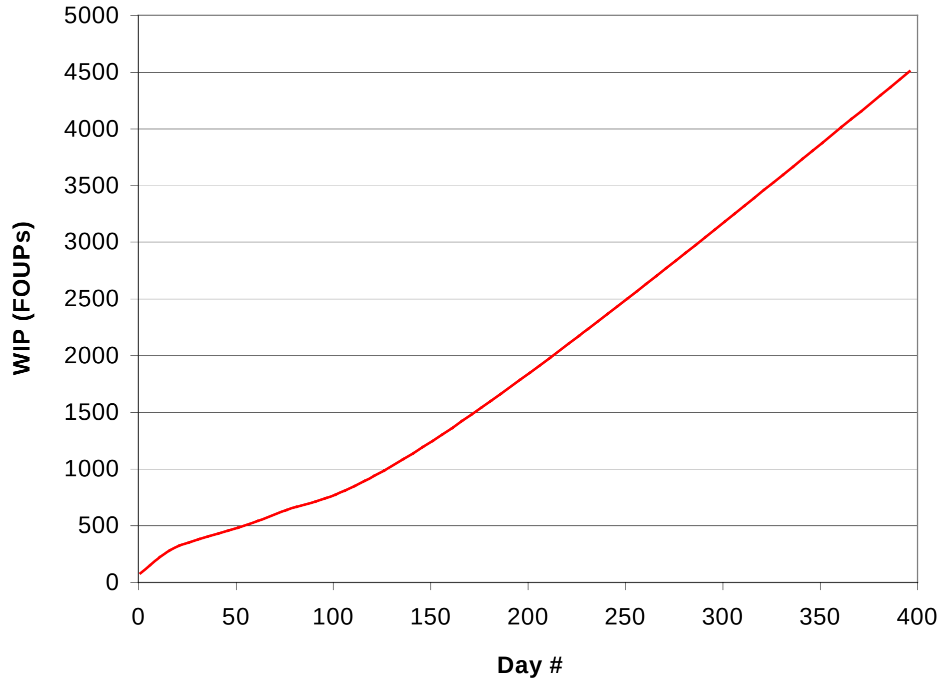


Figure 23 WIP Evolution with Wet Bench Buffer Size = 2 and Furnace Buffer Size = 4

Table 14 shows the results for the four models that reached steady state. The results seem to be counter-intuitive. As the buffer sizes decrease, the average WIP and cycle time also decrease. The most probable explanation for this is that with larger buffer sizes, lots are sent to busy tools with space in their buffers. While lots do try to avoid busy tools when possible, if none of the appropriate tools for the lot's current step are idle, the lot is sent to a busy tool with space in the buffer. This tool may not be close to being able to process the lot. There may be several batches already waiting at the tool, or the tool even may go down before working on the lot. With the exception of hot lots, lots cannot leave the tool to find a more available tool. Another tool may have been able to process the lot more quickly, but the lot was not routed to that tool. Because there is space for fewer lots in each buffer as buffer sizes decrease, fewer lots will wait at a tool while it works on other lots or goes down. Eventually, the decreased buffer capacity can no longer handle the traffic that needs to be routed through the batch tools. At that point, lots begin to back up in the stockers and the WIP in the system increases constantly. Table 15 shows the average and maximum time spent by lots in the buffers of each type of batch tool and the average and maximum WIP level in tool type's buffers. Table 16 provides the average and maximum time spent in each stocker and the average and maximum WIP level in each stocker.

Table 14 Buffer Experiment Results

	Wet Bench: 10 Furnace: 12	Wet Bench: 8 Furnace: 10	Wet Bench: 6 Furnace: 8	Wet Bench: 4 Furnace: 6
Length of one replication	900 Days	900 Days	900 Days	900 Days
Number of replications	1	1	1	1
Tool Count	277 Tools	277 Tools	277 Tools	277 Tools
Average Cycle Time	20.8 Days	20.2 Days	19.8 Days	19.2 Days
Average Factory WIP Level	609.4 FOUPs	593.4 FOUPs	580.8 FOUPs	563.0 FOUPs
Average Regular Lot Cycle Time	21.2 Days	20.8 Days	20.2 Days	19.6 Days
Average Regular Lot WIP Level	572.1 FOUPs	544.0 FOUPs	545.6 FOUPs	528.9 FOUPs
Average Hot Lot Cycle Time	14.0 Days	14.0 Days	14.1 Days	14.2 Days
Average Hot Lot WIP Level	4.7 FOUPs	4.6 FOUPs	4.7 FOUPs	4.7 FOUPs
Average NPW Cycle Time	16.3 Days	15.8 Days	15.3 Days	14.7 Days
Average NPW WIP Level	32.6 FOUPs	30.9 FOUPs	30.5 FOUPs	24.4 FOUPs
Factory average OEE	66%	66%	66%	66%

Table 15 Buffer Statistics

Tool	Average Time in Buffer					Average WIP in Buffer				
	Wet Bench: 10 Furnace: 12	Wet Bench: 8 Furnace: 10	Wet Bench: 6 Furnace: 8	Wet Bench: 4 Furnace: 6	Wet Bench: 2 Furnace: 4	Wet Bench: 10 Furnace: 12	Wet Bench: 8 Furnace: 10	Wet Bench: 6 Furnace: 8	Wet Bench: 4 Furnace: 6	Wet Bench: 2 Furnace: 4
Furn_FastRmp	3.37	3.12	2.77	2.42	1.99	4.94	4.58	4.07	3.56	0.44
Furn_Nitr	5.19	4.90	4.65	4.19	3.63	4.23	4.00	3.79	3.41	0.47
Furn_OxAn_I	5.41	4.94	4.44	3.83	2.97	4.87	4.45	4.00	3.44	0.36
Furn_OxAn_I_F	5.10	4.72	4.38	3.06	2.78	6.25	5.78	5.37	3.74	0.46
Furn_Poly	3.85	3.67	3.58	3.01	2.74	3.14	2.99	2.92	2.46	0.33
Furn_TEOS	3.55	3.38	3.26	2.85	2.70	2.89	2.75	2.66	2.32	0.31
Wet_Bench	0.16	0.16	0.16	0.17	0.16	1.41	1.44	1.38	1.47	1.05
Wet_Bench_I	0.15	0.17	0.16	0.14	0.15	1.19	1.34	1.27	1.14	0.67
Wet_Bench_I_F	0.18	0.18	0.18	0.16	0.16	0.90	0.90	0.87	0.79	0.11

Tool	Maximum Time in Buffer					Maximum WIP in Buffer				
	Wet Bench: 10 Furnace: 12	Wet Bench: 8 Furnace: 10	Wet Bench: 6 Furnace: 8	Wet Bench: 4 Furnace: 6	Wet Bench: 2 Furnace: 4	Wet Bench: 10 Furnace: 12	Wet Bench: 8 Furnace: 10	Wet Bench: 6 Furnace: 8	Wet Bench: 4 Furnace: 6	Wet Bench: 2 Furnace: 4
Furn_FastRmp	165.67	186.03	98.66	96.99	26.43	12	10	8	6	4
Furn_Nitr	38.93	41.15	57.32	30.23	18.17	12	10	8	6	4
Furn_OxAn_I	430.39	246.09	205.04	139.61	24.39	12	10	8	6	4
Furn_OxAn_I_F	57.40	38.33	32.83	28.27	15.41	12	10	8	6	4
Furn_Poly	42.54	41.30	36.98	31.82	22.72	12	10	8	6	4
Furn_TEOS	43.44	43.00	21.34	38.41	23.14	12	10	8	6	4
Wet_Bench	61.95	56.14	65.50	72.12	134.86	10	8	6	4	2
Wet_Bench_I	543.65	1483.81	3259.67	56.48	226.66	9	8	6	4	2
Wet_Bench_I_F	28.03	28.44	28.87	22.87	14.59	10	8	6	4	2

Table 16 Buffer Experiment Stocker Statistics

Stocker	Storage	Average Time in Stocker					Average WIP in Stocker				
		Wet Bench: 10 Furnace: 12	Wet Bench: 8 Furnace: 10	Wet Bench: 6 Furnace: 8	Wet Bench: 4 Furnace: 6	Wet Bench: 2 Furnace: 4	Wet Bench: 10 Furnace: 12	Wet Bench: 8 Furnace: 10	Wet Bench: 6 Furnace: 8	Wet Bench: 4 Furnace: 6	Wet Bench: 2 Furnace: 4
Implant	Ast1_stor	0.74	0.72	0.74	0.72	0.83	14.51	14.04	14.5	14.15	2.38
CMP	Bst1_stor	0.37	0.36	0.35	0.30	0.20	15.08	14.42	14.26	12.19	1.01
Photolithography	Cst1_stor	0.09	0.08	0.08	0.08	0.04	3.75	3.61	3.74	3.56	0.19
CMP	Dst1_stor	0.26	0.24	0.24	0.24	0.21	7.91	7.52	7.54	7.34	0.83
Photolithography	Est1_stor	0.10	0.09	0.10	0.09	0.07	4.69	4.47	4.52	4.46	0.41
Wet Area BEOL	Fst1_stor	0.19	0.19	0.19	0.19	3.01	9.7	9.57	9.71	9.68	24.45
Photolithography	Gst1_stor	0.04	0.04	0.04	0.04	0.04	1.2	1.21	1.21	1.2	0.17
Wet Area BEOL	Hst1_stor	0.21	0.21	0.21	0.21	2.60	10.5	10.39	10.52	10.54	27.5
Photolithography	Ist1_stor	0.13	0.12	0.13	0.12	0.05	7.14	6.86	7.09	6.64	0.34
Wet Area FEOL	Jst1_stor	0.22	0.23	0.23	0.23	0.71	11.22	11.39	11.25	11.33	4383.48
Etch & Strip FEOL	Kst1_stor	0.20	0.19	0.21	0.20	0.17	3.07	2.92	3.31	3.09	0.38
Furnace & RTP	Lst1_stor	0.31	0.31	0.31	0.42	0.50	9.6	9.71	9.79	13.31	3.15
Etch & Strip FEOL	Mst1_stor	0.10	0.09	0.10	0.09	0.08	2.52	2.4	2.47	2.43	0.29
Furnace & RTP	Nst1_stor	0.49	0.52	0.60	0.82	0.74	14.61	15.36	17.74	24.36	3.83
Etch & Strip BEOL	Ost1_stor	0.05	0.05	0.05	0.05	0.03	1.04	1	1.08	0.96	0.08
Metal Dep	Pst1_stor	0.13	0.12	0.13	0.13	0.03	1.87	1.78	1.84	1.84	0.06
Etch & Strip BEOL	Qst1_stor	0.07	0.06	0.06	0.06	0.03	0.97	0.94	0.88	0.87	0.06
Metal Dep	Rst1_stor	0.14	0.13	0.14	0.13	0.04	2.56	2.36	2.55	2.43	0.1
Etch & Strip BEOL	Sst1_stor	0.12	0.13	0.13	0.13	0.15	1.42	1.57	1.56	1.53	0.25
Metal Dep	Tst1_stor	0.25	0.25	0.25	0.26	0.19	1.85	1.89	1.85	1.94	0.19
Test	Ust1_stor	0.04	0.04	0.04	0.04	0.04	0.76	0.76	0.75	0.74	0.09
CVD BEOL	Vst1_stor	0.08	0.08	0.08	0.08	0.04	2.43	2.35	2.44	2.36	0.16
CVD BEOL	Xst1_stor	0.52	0.48	0.49	0.47	0.37	14.12	13.06	13.5	12.86	1.37

Stocker	Storage	Maximum Time in Stocker					Maximum WIP in Stocker				
		Wet Bench: 10 Furnace: 12	Wet Bench: 8 Furnace: 10	Wet Bench: 6 Furnace: 8	Wet Bench: 4 Furnace: 6	Wet Bench: 2 Furnace: 4	Wet Bench: 10 Furnace: 12	Wet Bench: 8 Furnace: 10	Wet Bench: 6 Furnace: 8	Wet Bench: 4 Furnace: 6	Wet Bench: 2 Furnace: 4
Implant	Ast1_stor	66.92	68.25	68.37	66.38	54.72	124	116	117	113	87
CMP	Bst1_stor	36.40	35.18	38.56	36.75	20.18	71	75	72	63	33
Photolithography	Cst1_stor	10.53	10.45	9.86	8.98	0.56	44	51	43	44	10
CMP	Dst1_stor	61.28	50.41	49.17	49.31	23.94	83	67	68	68	42
Photolithography	Est1_stor	16.84	18.84	18.41	37.08	5.92	53	57	47	61	23
Wet Area BEOL	Fst1_stor	23.50	21.53	28.73	18.36	36.69	43	47	42	46	272
Photolithography	Gst1_stor	2.30	2.64	2.61	2.56	1.06	15	20	19	17	11
Wet Area BEOL	Hst1_stor	44.48	51.94	50.66	52.00	36.49	65	79	77	77	276
Photolithography	Ist1_stor	13.36	15.98	13.08	15.99	2.77	58	59	55	49	15
Wet Area FEOL	Jst1_stor	69.57	69.42	64.73	62.94	47.91	38	35	36	35	10146
Etch & Strip FEOL	Kst1_stor	14.29	10.98	12.09	13.00	8.58	60	49	53	54	37
Furnace & RTP	Lst1_stor	36.00	59.44	39.91	41.04	29.32	42	45	48	67	56
Etch & Strip FEOL	Mst1_stor	14.54	13.48	14.93	24.74	8.19	40	37	36	46	20
Furnace & RTP	Nst1_stor	42.28	36.37	51.50	41.19	27.71	80	85	102	102	84
Etch & Strip BEOL	Ost1_stor	2.34	2.02	3.71	2.48	0.55	30	28	48	25	10
Metal Dep	Pst1_stor	11.21	9.12	8.67	9.67	1.04	78	63	63	71	9
Etch & Strip BEOL	Qst1_stor	3.56	3.17	3.20	3.20	0.58	31	30	30	30	6
Metal Dep	Rst1_stor	9.81	9.54	10.91	10.84	0.85	78	70	74	76	7
Etch & Strip BEOL	Sst1_stor	23.06	24.52	21.23	25.89	20.31	31	38	37	44	43
Metal Dep	Tst1_stor	21.98	23.77	23.49	24.40	8.67	42	45	44	43	16
Test	Ust1_stor	2.53	1.68	1.87	1.10	0.59	37	20	27	22	9
CVD BEOL	Vst1_stor	4.53	4.83	4.64	4.54	0.80	38	35	35	42	9
CVD BEOL	Xst1_stor	53.70	53.43	56.04	52.16	36.31	107	96	115	102	76

9 NEXT STEPS

In the next year, several more experiments are planned. Experiments to be performed include having NPWs run shorter routes that only go through the litho and etch bays, including more than two process flows, having multiple lots per pod, and modeling multiple part numbers. Another planned experiment is to model the intrabay and interbay systems as one combined transport system. In addition, the factory modeling project will be combined with the International SEMATECH cost modeling project. The factory modeling team will provide dynamic simulation results for the static cost models. The dynamic results will allow the cost modeling team to include more realistic tool counts in the static models.

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APPENDIX A: 180 nm ALUMINUM PROCESS FLOW

Process #	Process Step	Tool Name	Throughput (wafers /hour) [1]	Processing Time (min/wafer) [2]	Maximum # of FOUPs/Batch [3]	Process Time (hrs per batch or FOUP) [4]
1	Clean_Pre_OxAn	Wet_Bench	150.00	0.40	2	0.33
2	Oxidation_Sac	Furn_FastRmp	30.00	2.00	4	3.33
3	Meas_Film	Meas_Film	200.00	0.30	1	0.13
4	LPCVD_Nitride	Furn_Nitr	15.00	4.00	4	6.67
5	Meas_Film	Meas_Film	200.00	0.30	1	0.13
6	Expose_AA	Litho_248	30.00	2.00	1	0.83
7	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
8	Meas_CD	Meas_CD	100.00	0.60	1	0.25
9	Etch_AA	Dry_Etch_A	15.00	4.00	1	1.67
10	Plasma_Strip	Dry_Strip	40.00	1.50	1	0.63
11	Clean_O3	VP_HF_Clean	25.00	2.40	1	1.00
12	Clean_Post_Strip	Wet_Bench	150.00	0.40	2	0.33
13	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
14	Meas_CD	Meas_CD	100.00	0.60	1	0.25
15	Clean_Pre_OxAn	Wet_Bench	150.00	0.40	2	0.33
16	Oxidation	Furn_FastRmp	30.00	2.00	4	3.33
17	Meas_Film	Meas_Film	200.00	0.30	1	0.13
18	Oxide_STI	CVD_Ins	45.00	1.33	1	0.56
19	Meas_Film	Meas_Film	200.00	0.30	1	0.13
20	Densification	Furn_FastRmp	30.00	2.00	4	3.33
21	CMP_AA	CMP_Ins	40.00	1.50	1	0.63
22	Wet_Strip	Wet_Bench	150.00	0.40	2	0.33
23	Dry_Strip	Dry_Strip_D	50.00	1.20	1	0.50
24	Clean_Pre_OxAn	Wet_Bench	150.00	0.40	2	0.33
25	Oxidation_Sac	Furn_FastRmp	30.00	2.00	4	3.33
26	Meas_Film	Meas_Film	200.00	0.30	1	0.13
27	Expose_Implant	Litho_I	30.00	2.00	1	0.83
28	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
29	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
30	Meas_CD	Meas_CD	100.00	0.60	1	0.25
31	Implant	Implant_HiE	95.00	0.63	1	0.26
32	Implant	Implant_HiE	95.00	0.63	1	0.26
33	Implant	Implant_LoE	70.00	0.86	1	0.36
34	Plasma_Strip	Dry_Strip	40.00	1.50	1	0.63
35	Clean_Post_Strip	Wet_Bench	150.00	0.40	2	0.33

[1] A1 (based on your inputs)
[2] B1 = 60/A1
[3] C1
[4] D1 = 25 * (C1/A1)

Process #	Process Step	Tool Name	Throughput (wafers /hour) [1]	Processing Time (min/wafer) [2]	Maximum # of FOUPs/Batch [3]	Process Time (hrs per batch or FOUP) [4]
36	Expose_Implant	Litho_I	30.00	2.00	1	0.83
37	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
38	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
39	Meas_CD	Meas_CD	100.00	0.60	1	0.25
40	Implant	Implant_HiE	95.00	0.63	1	0.26
41	Implant	Implant_HiE	95.00	0.63	1	0.26
42	Implant	Implant_LoE	70.00	0.86	1	0.36
43	Plasma_Strip	Dry_Strip	40.00	1.50	1	0.63
44	Clean_Post_Strip	Wet_Bench	150.00	0.40	2	0.33
45	Wet_Strip	Wet_Bench	150.00	0.40	2	0.33
46	Clean_O3	VP_HF_Clean	120.00	0.50	1	0.21
47	Oxidation_Gate	Furn_FastRmp	30.00	2.00	4	3.33
48	Meas_Film	Meas_Film	200.00	0.30	1	0.13
49	LPCVD_Poly	Furn_Poly	20.00	3.00	4	5.00
50	Meas_Film	Meas_Film	200.00	0.30	1	0.13
51	Expose_Gate	Litho_248	30.00	2.00	1	0.83
52	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
53	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
54	Meas_CD	Meas_CD	100.00	0.60	1	0.25
55	Etch_Gate	Dry_Etch	15.00	4.00	1	1.67
56	Meas_Film	Meas_Film	200.00	0.30	1	0.13
57	Inspect_Visual	Insp_Visual	200.00	0.30	1	0.13
58	Plasma_Strip	Dry_Strip	40.00	1.50	1	0.63
59	Clean_Post_Strip	Wet_Bench	150.00	0.40	2	0.33
60	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
61	Meas_CD	Meas_CD	100.00	0.60	1	0.25
62	Clean_Pre_OxAn	Wet_Bench	150.00	0.40	2	0.33
63	Oxidation	Furn_FastRmp	30.00	2.00	4	3.33
64	Meas_Film	Meas_Film	200.00	0.30	1	0.13
65	Expose_Implant	Litho_I	30.00	2.00	1	0.83
66	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
67	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
68	Meas_CD	Meas_CD	100.00	0.60	1	0.25
69	Implant	Implant_LoE	70.00	0.86	1	0.36
70	Plasma_Strip	Dry_Strip	40.00	1.50	1	0.63
71	Clean_Post_Strip	Wet_Bench	150.00	0.40	2	0.33
72	Expose_Implant	Litho_I	30.00	2.00	1	0.83
73	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25

[1] A1 (based on your inputs)
[2] B1 = 60/A1
[3] C1
[4] D1 = 25 * (C1/A1)

Process #	Process Step	Tool Name	Throughput (wafers /hour) [1]	Processing Time (min/wafer) [2]	Maximum # of FOUPs/Batch [3]	Process Time (hrs per batch or FOUP) [4]
74	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
75	Meas_CD	Meas_CD	100.00	0.60	1	0.25
76	Implant	Implant_LoE	70.00	0.86	1	0.36
77	Plasma_Strip	Dry_Strip	40.00	1.50	1	0.63
78	Clean_Post_Strip	Wet_Bench	150.00	0.40	2	0.33
79	Clean_Pre_OxAn	Wet_Bench	150.00	0.40	2	0.33
80	LPCVD_TEOS	Furn_TEOS	20.00	3.00	4	5.00
81	Meas_Film	Meas_Film	200.00	0.30	1	0.13
82	Etch_Spacer	Dry_Etch	15.00	4.00	1	1.67
83	Meas_Film	Meas_Film	200.00	0.30	1	0.13
84	Clean_Pre_OxAn	Wet_Bench	150.00	0.40	2	0.33
85	RTP_Anneal/Ox	RTP_OxAn	40.00	1.50	1	0.63
86	Meas_Film	Meas_Film	200.00	0.30	1	0.13
87	Expose_Implant	Litho_I	30.00	2.00	1	0.83
88	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
89	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
90	Meas_CD	Meas_CD	100.00	0.60	1	0.25
91	Implant	Implant_LoE	70.00	0.86	1	0.36
92	Plasma_Strip	Dry_Strip	40.00	1.50	1	0.63
93	Clean_Post_Strip	Wet_Bench	150.00	0.40	2	0.33
94	Expose_Implant	Litho_I	30.00	2.00	1	0.83
95	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
96	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
97	Meas_CD	Meas_CD	100.00	0.60	1	0.25
98	Implant	Implant_LoE	70.00	0.86	1	0.36
99	Plasma_Strip	Dry_Strip	40.00	1.50	1	0.63
100	Clean_Post_Strip	Wet_Bench	150.00	0.40	2	0.33
101	Clean_Pre_OxAn	Wet_Bench	150.00	0.40	2	0.33
102	RTP_Anneal	RTP_OxAn	40.00	1.50	1	0.63
103	Dry_Strip	Dry_Etch	15.00	4.00	1	1.67
104	Meas_Film	Meas_Film	200.00	0.30	1	0.13
105	Plasma_Strip	Dry_Strip_I	55.00	1.09	1	0.45
106	Clean_Post_Strip	Wet_Bench	150.00	0.40	2	0.33
107	Clean_O3	VP_HF_Clean	25.00	2.40	1	1.00
108	PVD_Ti/Co	PVD_Met_C	30.00	2.00	1	0.83
109	Inspect_Visual	Insp_Visual	200.00	0.30	1	0.13
110	RTP_Silicide	RTP_OxAn_C	35.00	1.71	1	0.71
111	Wet_Strip Ti/Co	Wet_Bench_I	170.00	0.35	2	0.29

[1] A1 (based on your inputs)
[2] B1 = 60/A1
[3] C1
[4] D1 = 25 * (C1/A1)

Process #	Process Step	Tool Name	Throughput (wafers /hour) [1]	Processing Time (min/wafer) [2]	Maximum # of FOUPs/Batch [3]	Process Time (hrs per batch or FOUP) [4]
112	RTP_Anneal	RTP_OxAn_C	35.00	1.71	1	0.71
113	CVD_Nitr/TEOS	CVD_Ins_C	45.00	1.33	1	0.56
114	Meas_Film	Meas_Film	200.00	0.30	1	0.13
115	CVD_BPSG	CVD_Ins_C	45.00	1.33	1	0.56
116	Meas_Film	Meas_Film	200.00	0.30	1	0.13
117	Densification	Furn_OxAn_I	20.00	3.00	4	5.00
118	CMP_BPSG	CMP_Ins_C	40.00	1.50	1	0.63
119	Meas_Film	Meas_Film	200.00	0.30	1	0.13
120	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
121	APCVD_Ox	CVD_Ins_C	45.00	1.33	1	0.56
122	Expose_Contact	Litho_248	30.00	2.00	1	0.83
123	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
124	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
125	Meas_CD	Meas_CD	100.00	0.60	1	0.25
126	Etch_Contact	Dry_Etch_C	25.00	2.40	1	1.00
127	Plasma_Strip	Dry_Strip_I	55.00	1.09	1	0.45
128	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29
129	Meas_CD	Meas_CD	100.00	0.60	1	0.25
130	CVD_Ti/TiN	CVD_Met_C	35.00	1.71	1	0.71
131	CVD_W	CVD_MetW_C	35.00	1.71	1	0.71
132	CMP_W	CMP_Met	40.00	1.50	1	0.63
133	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
134	PVD_Al/Cu	PVD_Met	30.00	2.00	1	0.83
135	CVD_Oxide	CVD_Ins_Thin	80.00	0.75	1	0.31
136	Expose_Line	Litho_248	30.00	2.00	1	0.83
137	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
138	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
139	Meas_CD	Meas_CD	100.00	0.60	1	0.25
140	Etch_Mask	Dry_Etch_I	25.00	2.40	1	1.00
141	Etch_Metal	Dry_Etch_Met	20.00	3.00	1	1.25
142	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29
143	Meas_CD	Meas_CD	100.00	0.60	1	0.25
144	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
145	Anneal_Metal	Furn_OxAn_I	20.00	3.00	4	5.00
146	Test	Test	15.00	4.00	1	1.67
147	Clean_Metal	Wet_Bench_I	170.00	0.35	2	0.29
148	CVD_ILD	CVD_Ins_I	30.00	2.00	1	0.83
149	Meas_Film	Meas_Film	200.00	0.30	1	0.13

[1] A1 (based on your inputs)
[2] B1 = 60/A1
[3] C1
[4] D1 = 25 * (C1/A1)

Process #	Process Step	Tool Name	Throughput (wafers /hour) [1]	Processing Time (min/wafer) [2]	Maximum # of FOUPs/Batch [3]	Process Time (hrs per batch or FOUP) [4]
150	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
151	CMP_Oxide	CMP_Ins_I	35.00	1.71	1	0.71
152	Meas_Film	Meas_Film	200.00	0.30	1	0.13
153	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
154	Expose_Via	Litho_248	30.00	2.00	1	0.83
155	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
156	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
157	Meas_CD	Meas_CD	100.00	0.60	1	0.25
158	Etch_Via	Dry_Etch_I	30.00	2.00	1	0.83
159	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29
160	Meas_CD	Meas_CD	100.00	0.60	1	0.25
161	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
162	Clean_Metal	Wet_Bench_I	170.00	0.35	2	0.29
163	CVD_Ti/TiN	CVD_Met	30.00	2.00	1	0.83
164	CVD_W	CVD_MetW	35.00	1.71	1	0.71
165	CMP_W	CMP_Met	40.00	1.50	1	0.63
166	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
167	PVD_Al/Cu	PVD_Met	30.00	2.00	1	0.83
168	CVD_Oxide	CVD_Ins_Thin	80.00	0.75	1	0.31
169	Expose_Line	Litho_248	30.00	2.00	1	0.83
170	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
171	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
172	Meas_CD	Meas_CD	100.00	0.60	1	0.25
173	Etch_Mask	Dry_Etch_I	25.00	2.40	1	1.00
174	Etch_Metal	Dry_Etch_Met	20.00	3.00	1	1.25
175	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29
176	Meas_CD	Meas_CD	100.00	0.60	1	0.25
177	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
178	Anneal_Metal	Furn_OxAn_I	20.00	3.00	4	5.00
179	Test	Test	15.00	4.00	1	1.67
180	Clean_Metal	Wet_Bench_I	170.00	0.35	2	0.29
181	CVD_ILD	CVD_Ins_I	30.00	2.00	1	0.83
182	Meas_Film	Meas_Film	200.00	0.30	1	0.13
183	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
184	CMP_Oxide	CMP_Ins_I	35.00	1.71	1	0.71
185	Meas_Film	Meas_Film	200.00	0.30	1	0.13
186	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
187	Expose_Via	Litho_248	30.00	2.00	1	0.83

[1] A1 (based on your inputs)
[2] B1 = 60/A1
[3] C1
[4] D1 = 25 * (C1/A1)

Process #	Process Step	Tool Name	Throughput (wafers /hour) [1]	Processing Time (min/wafer) [2]	Maximum # of FOUPs/Batch [3]	Process Time (hrs per batch or FOUP) [4]
188	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
189	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
190	Meas_CD	Meas_CD	100.00	0.60	1	0.25
191	Etch_Via	Dry_Etch_I	30.00	2.00	1	0.83
192	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29
193	Meas_CD	Meas_CD	100.00	0.60	1	0.25
194	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
195	Clean_Metal	Wet_Bench_I	170.00	0.35	2	0.29
196	CVD_Ti/TiN	CVD_Met	30.00	2.00	1	0.83
197	CVD_W	CVD_MetW	35.00	1.71	1	0.71
198	CMP_W	CMP_Met	40.00	1.50	1	0.63
199	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
200	PVD_Al/Cu	PVD_Met	30.00	2.00	1	0.83
201	CVD_Oxide	CVD_Ins_Thin	80.00	0.75	1	0.31
202	Expose_Line	Litho_I	30.00	2.00	1	0.83
203	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
204	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
205	Meas_CD	Meas_CD	100.00	0.60	1	0.25
206	Etch_Mask	Dry_Etch_I	25.00	2.40	1	1.00
207	Etch_Metal	Dry_Etch_Met	20.00	3.00	1	1.25
208	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29
209	Meas_CD	Meas_CD	100.00	0.60	1	0.25
210	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
211	Anneal_Metal	Furn_OxAn_I	20.00	3.00	4	5.00
212	Test	Test	15.00	4.00	1	1.67
213	Clean_Metal	Wet_Bench_I	170.00	0.35	2	0.29
214	CVD_ILD	CVD_Ins_I	30.00	2.00	1	0.83
215	Meas_Film	Meas_Film	200.00	0.30	1	0.13
216	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
217	CMP_Oxide	CMP_Ins_I	35.00	1.71	1	0.71
218	Meas_Film	Meas_Film	200.00	0.30	1	0.13
219	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
220	Expose_Via	Litho_248	30.00	2.00	1	0.83
221	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
222	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
223	Meas_CD	Meas_CD	100.00	0.60	1	0.25
224	Etch_Via	Dry_Etch_I	30.00	2.00	1	0.83
225	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29

[1] A1 (based on your inputs)
[2] B1 = 60/A1
[3] C1
[4] D1 = 25 * (C1/A1)

Process #	Process Step	Tool Name	Throughput (wafers /hour) [1]	Processing Time (min/wafer) [2]	Maximum # of FOUPs/Batch [3]	Process Time (hrs per batch or FOUP) [4]
226	Meas_CD	Meas_CD	100.00	0.60	1	0.25
227	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
228	Clean_Metal	Wet_Bench_I	170.00	0.35	2	0.29
229	CVD_Ti/TiN	CVD_Met	30.00	2.00	1	0.83
230	CVD_W	CVD_MetW	35.00	1.71	1	0.71
231	CMP_W	CMP_Met	40.00	1.50	1	0.63
232	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
233	PVD_Al/Cu	PVD_Met	30.00	2.00	1	0.83
234	CVD_Oxide	CVD_Ins_Thin	80.00	0.75	1	0.31
235	Expose_Line	Litho_I	30.00	2.00	1	0.83
236	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
237	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
238	Meas_CD	Meas_CD	100.00	0.60	1	0.25
239	Etch_Mask	Dry_Etch_I	25.00	2.40	1	1.00
240	Etch_Metal	Dry_Etch_Met	20.00	3.00	1	1.25
241	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29
242	Meas_CD	Meas_CD	100.00	0.60	1	0.25
243	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
244	Anneal_Metal	Furn_OxAn_I	20.00	3.00	4	5.00
245	Test	Test	15.00	4.00	1	1.67
246	Clean_Metal	Wet_Bench_I	170.00	0.35	2	0.29
247	CVD_ILD	CVD_Ins_I	30.00	2.00	1	0.83
248	Meas_Film	Meas_Film	200.00	0.30	1	0.13
249	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
250	CMP_Oxide	CMP_Ins_I	35.00	1.71	1	0.71
251	Meas_Film	Meas_Film	200.00	0.30	1	0.13
252	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
253	Expose_Via	Litho_I	30.00	2.00	1	0.83
254	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
255	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
256	Meas_CD	Meas_CD	100.00	0.60	1	0.25
257	Etch_Via	Dry_Etch_I	30.00	2.00	1	0.83
258	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29
259	Meas_CD	Meas_CD	100.00	0.60	1	0.25
260	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
261	Clean_Metal	Wet_Bench_I	170.00	0.35	2	0.29
262	CVD_Ti/TiN	CVD_Met	30.00	2.00	1	0.83
263	CVD_W	CVD_MetW	35.00	1.71	1	0.71

[1] A1 (based on your inputs)
[2] B1 = 60/A1
[3] C1
[4] D1 = 25 * (C1/A1)

Process #	Process Step	Tool Name	Throughput (wafers /hour) [1]	Processing Time (min/wafer) [2]	Maximum # of FOUPs/Batch [3]	Process Time (hrs per batch or FOUP) [4]
264	CMP_W	CMP_Met	40.00	1.50	1	0.63
265	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
266	PVD_Al/Cu	PVD_Met	30.00	2.00	1	0.83
267	Expose_Line	Litho_Iw	35.00	1.71	1	0.71
268	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
269	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
270	Meas_CD	Meas_CD	100.00	0.60	1	0.25
271	Etch_Metal	Dry_Etch_Met	20.00	3.00	1	1.25
272	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29
273	Meas_CD	Meas_CD	100.00	0.60	1	0.25
274	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
275	Anneal_Metal	Furn_OxAn_I	20.00	3.00	4	5.00
276	Test	Test	15.00	4.00	1	1.67
277	Clean_Metal	Wet_Bench_I	170.00	0.35	2	0.29
278	CVD_ILD	CVD_Ins_I	30.00	2.00	1	0.83
279	Meas_Film	Meas_Film	200.00	0.30	1	0.13
280	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
281	CMP_Oxide	CMP_Ins_I	35.00	1.71	1	0.71
282	Meas_Film	Meas_Film	200.00	0.30	1	0.13
283	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
284	Expose_Via	Litho_I	30.00	2.00	1	0.83
285	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
286	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
287	Meas_CD	Meas_CD	100.00	0.60	1	0.25
288	Etch_Via	Dry_Etch_I	30.00	2.00	1	0.83
289	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29
290	Meas_CD	Meas_CD	100.00	0.60	1	0.25
291	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
292	Clean_Metal	Wet_Bench_I	170.00	0.35	2	0.29
293	CVD_Ti/TiN	CVD_Met	30.00	2.00	1	0.83
294	CVD_W	CVD_MetW	35.00	1.71	1	0.71
295	CMP_W	CMP_Met	40.00	1.50	1	0.63
296	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
297	PVD_Al/Cu	PVD_Met	30.00	2.00	1	0.83
298	Expose_Line	Litho_Iw	35.00	1.71	1	0.71
299	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
300	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
301	Meas_CD	Meas_CD	100.00	0.60	1	0.25

[1] A1 (based on your inputs)
[2] B1 = 60/A1
[3] C1
[4] D1 = 25 * (C1/A1)

Process #	Process Step	Tool Name	Throughput (wafers /hour) [1]	Processing Time (min/wafer) [2]	Maximum # of FOUPs/Batch [3]	Process Time (hrs per batch or FOUP) [4]
302	Etch_Metal	Dry_Etch_Met	20.00	3.00	1	1.25
303	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29
304	Meas_CD	Meas_CD	100.00	0.60	1	0.25
305	Inspect_PLY	Insp_PLY	200.00	0.30	1	0.13
306	Anneal_Metal	Furn_OxAn_I	20.00	3.00	4	5.00
307	Test	Test	15.00	4.00	1	1.67
308	Clean_Metal	Wet_Bench_I	170.00	0.35	2	0.29
309	CVD_TEOS/Nitride	CVD_Ins_I	30.00	2.00	1	0.83
310	Expose_Pad	Litho_Iw	35.00	1.71	1	0.71
311	Meas_Overlay	Meas_Overlay	100.00	0.60	1	0.25
312	Etch_PAD	Dry_Etch_I	20.00	3.00	1	1.25
313	Plasma_Strip	Dry_Strip_I	55.00	1.09	1	0.45
314	Clean_Post_Strip	Wet_Bench_I	170.00	0.35	2	0.29
315	Anneal_Metal	Furn_OxAn_I	20.00	3.00	4	5.00
316	Test	Test	15.00	4.00	1	1.67
					Total Raw Processing Time (days)	8.90

[1] A1 (based on your inputs)
[2] B1 = 60/A1
[3] C1
[4] D1 = 25 * (C1/A1)

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