Published in: 2002 Semiconductor Equipment and Materials International

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Reducing Costs With the Farmed Fab Layout

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Advances in automated material handling systems (AMHS) make farm layout concepts an attractive cost reduction strategy for high volume 300mm semiconductor manufacturers. A farm layout, or group technology layout, arranges like equipment together offering reduced construction and operating costs and a shortened Fab design/ construction cycle. Relatively minor increases to AMHS capacity are required in the farm scenario to ensure that tool utilization and product cycle-time are not adversely impacted. Cost reductions and schedule improvements associated with the farm layout, outweigh the relatively small AMHS cost additions required to implement them.

Introduction

In Charles Darwin's popular game Natural Selection, organisms compete in a changing environment and either adapt or die out. Likewise, as the semiconductor industry evolves, manufacturers' are continually challenged to recognize change and adapt. A recent pivotal change in the world of the 300mm high volume manufacturer, is the availability of Unified AMHS or direct point to point transport. Future world-class survivors of the 300mm fab game will have comprehended this change and optimized their fab layouts accordingly.

Traditionally, semiconductor manufacturers seeking the lowest process cycle time, have arranged their equipment to minimize the travel distance of material between process steps. This approach, focused on process flow, results in tools of different sizes being placed adjacent to each other at the expense of efficient use of Fab space.
In contrast, a farm layout arrangement, groups like equipment together analogous to the way a farmer plants crops. Farm layouts offer the highest possible tool packing density simply because like equipment of like dimension fit together with the least amount of space wasted. Many other cost benefits also follow from collocating tools according to function and facility requirements. Although most fabs today employ a hybrid between these two extremes, advances in AMHS, tool design and operation are pushing the optimal balance point toward the farm concept.

In our brief survey of recent fab layout literature, we found many studies recognizing the need to thoroughly evaluate the advantages and disadvantages of farm and flow concepts, but few discussing how improvements in 300mm AMHS integration might alter the parameters of the fab optimization problem. However, in the following excerpt from "Impact of AMHS on Design and Construction of 300mm Fabs" Merchant and Chasey do identify AMHS integration as a key enabler (1).

"The 300mm wafer fab transition presents several opportunities and challenges for designing the fab layout. The increased level of integration among the material handling system and the process tools allows enormous flexibility of tool layout. Tools no longer need to be grouped according to their process requirements. 'Virtual bays' allow tools to be placed anywhere in a cleanroom, yet they can be treated as if they were in one process bay."

This paper addresses the challenge mentioned above, by comparing a typical hybrid layout, to a nearly pure farm type layout, and evaluating each for relative impact to wafer cycle time, fab life cycle cost, and fab design/construct duration.

Description of Fab Concepts and Assumptions

In order to compare the relative merits of farm and hybrid flow layouts, we developed detailed layouts for each, using identical tool sets capable of producing approximately 6000 wafer starts per week. We assumed for both scenarios, a maximum distance of 100 feet from any point in the fab to an exit.

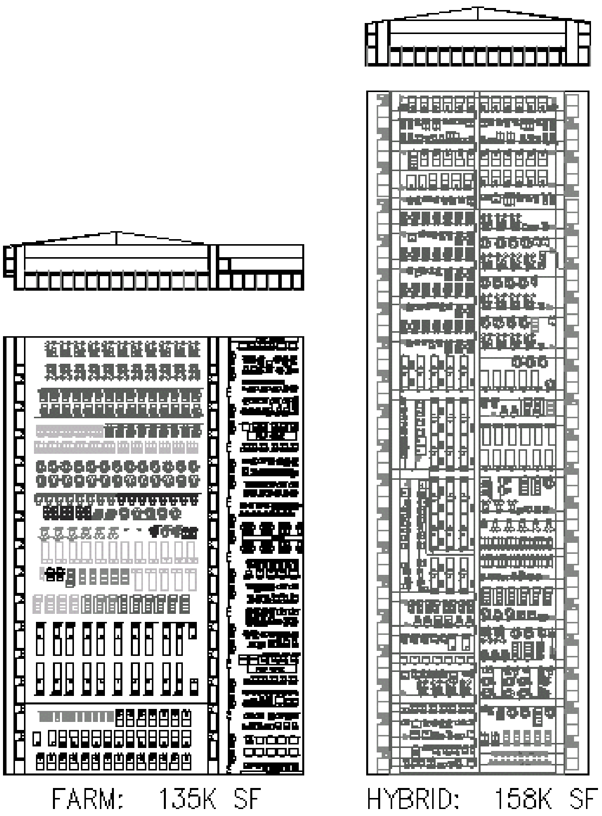

Figure 1: Basic Farm and Hybrid Fab Layout Concepts

Area Metrics:	Farm	Hybrid
Overall Area (SqFt)	135366	157680
Hazardous Occupancy (SqFt)	92300	141840
Non-Hazardous Occupancy (SqFt)	43066	15840
Non-waffle (SqFt)	43066	15840
Overall Length (Ft)	462	720
Overall Width (Ft)	293	219
Aspect Ratio L:W	1.6:1	3.3:1
MFG Space:	126226	140400

Utility Distribution Metrics:		
Solvent(Exhaust, Supply, Drain) Lineal (Ft)	720	2360
Acid Exhaust Lineal (Ft)	2009	3049
Spec Gas Lineal (Ft)	1020	2691
UPW/Drain Lineal (Ft)	1274.5	2721
Common Utilities Required in All Areas (Ft)	2824.5	3836

Table 1: Comparison of Fab Concepts

The hybrid flow layout shown in Figure 1 is the result of an earlier AMD/M+W Zander feasibility study. The layout includes limited use of flow based work cells, not unlike the farm/flow hybrid developed in the SEMATECH paper "300 mm Factory Layout and Material Handling Modeling" Phase I Report By Tim Quinn and Edward Bass (3). The farm layout arranges the tool set into groups of like equipment and then seeks to minimize facility costs by collocating groups with similar building and facilities requirements. Such requirements include utility services and the need for subfab equipment support space. Our team developed three detailed farm layout concepts using this approach and selected the concept shown in Figure 1 for our comparison study. This concept arranges process tools into a pure farm over a waffle table. Since metrology and wafer storage equipment have little need for subfab support space and have comparatively less facility requirements than value add processing equipment, we chose to group these functions together within a non-hazardous single level lower cost structure, separated from the waffle table by a fire rated exit corridor. This elongated metrology and storage section departs somewhat from the pure farm layout in locating metrology and stockers adjacent to the bays they support.

Comparison of Characteristics for Fab Concepts

The various metrics in the Table 1 reveal clear advantages of the farm over the hybrid. The farm layout footprint is 86% the size of the hybrid layout. The amount of hazardous building area (H6 in the UBC) in the farm layout is 65% of the hybrid. The utility distribution piping and ducting in the farm layout are measurably reduced in comparison to the hybrid layout.

Cycle Time and Tool Utilization

When considering a farm type layout, the primary concern is the impact to product cycle time and tool utilization.
This question deserves attention, since process equipment accounts for approximately 75% of the cost of a modern 300mm HVM fab (2).
The approach taken in our analysis is to add AMHS capacity to the farm scenario in order to ensure that cycle time and tool utilization are the same for both scenarios. For both the farm and hybrid layouts, we estimate delivery time will average 3 minutes with a maximum of 6 minutes. The chart below shows that the average and maximum transport times are, by and large, well below the process times for the AMD process. Thus, transportation should very rarely affect tool utilization and cycle time.

Wafer Lot Delivery Times

When designing automated material handling for each functional bay and the total system, it is important to make sure that at peak tool utilizations, the AMHS will have enough capacity to respond to peak throughput demands. Given sufficient capacity, tool cycle time and tool utilization will depend more on automation planning and scheduling than on factory layout. Production rules developed through manufacturing experience, simulation-modeling and scheduling software have been shown to make significant improvement in manufacturing cycle time. With the correct planning and logistics approach, fab industrial engineers should be able to manage historical bottleneck areas, reduce WIP and cycle time and utilize tools, including the AMHS, in a more efficient manner.

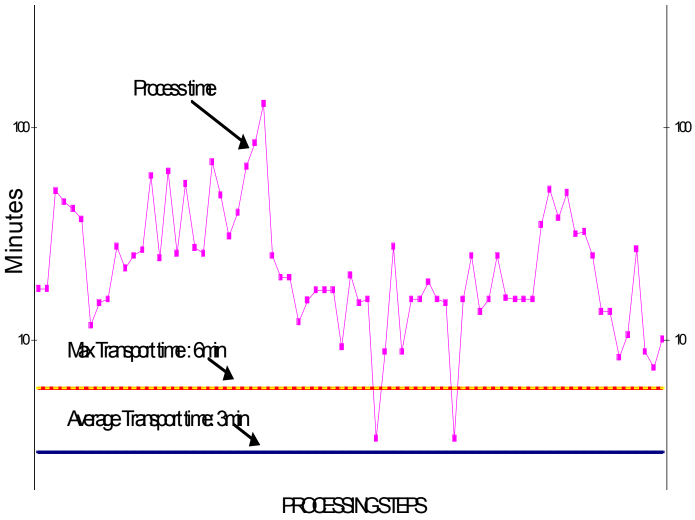

Figure 2: Transport Time Verses Processing Time

Comparison of Fab Capital Costs

We prepared detailed construction and AMHS cost estimates (see Table 2) for the farm and hybrid concepts using a baseline cost database and found that the combined cost of construction and AMHS for the farm concept is overall, 6% less than that of the hybrid concept.

Our construction cost estimates took into account the differences in fab areas and overall length of utility mains and laterals for the two layouts, but did not attempt to estimate the tool hookup savings expected from more uniform farm layouts.

Our estimate of the AMHS cost includes the payload transport capability, WIP storage and the transport control software. Because storage requirements were the same in both concepts (approximately 6000 FOUPS), the cost of the AMHS for each scenario becomes somewhat normalized. The storage requirement far exceeds the number of FOUP movement requirements.

Although overhead hoist point-to-point transport systems are used for each scenario, the two designs differ significantly from each other, due to the large differences in required bay to bay moves. The most significant changes are that more overhead hoist vehicles (OHV) and supporting track will be needed for the farm layout. Largely because of this difference, the farm layout AMHS cost is 17% higher than that of the Hybrid.
In addition to AMHS and construction capital costs, it should be noted that, although the tool sets used in the study were assumed to be identical in practice, a flow layout would typically require some additional tooling cost to achieve balanced workcells.

Operational Cost Advantages of Farm Layout

While quantifying operational cost differences between the farm and hybrid layouts is beyond the scope of this paper, it is clear to the authors that operating a farmed fab offers significant efficiencies in the areas of human resources, risk management and energy utilization.

Locating like tools together, maximizes efficiency for much of the workforce. When considering the hybrid layout, we should also consider the many job functions continually hampered by the shear size of a modern a HVM Fab.
By limiting each tool type to a smaller geographic area, we improve workflow and communication for wafer fab technicians, supervisors, vendor support, process engineers, etc. The role of personnel in the Fab will likely change as the level of automation and mechanization increases, the focus, shifting away from wafer handling and logistics, toward process improvement and tool optimization. The farm layout facilitates this shift more readily than the hybrid layout, since personnel can more easily be specialized around tool types rather than process bays.

Locating like tools together should improve uniformity of facility services within a given tool type, since each tool group will on average, see less variation in exhaust submains, utility distribution loops, gas systems, chemical supplies, etc. Greater uniformity simplifies the process engineer's job by reducing the number of processing parameters that must be considered.
The farm layout has the added benefit of naturally segregating hazards.
For example, solvent stations already farmed together, can more easily incorporate fire and smoke segregation, to limit potential for damage to the rest of the fab. Segregating metrology into a single non-hazardous area reduces the size of the overall hazardous building area and thus reduces risk to personnel and capital investment. This flexibility in layout allows the manufacturer to more easily incorporate risk mitigation measures that potentially reduce Fab insurance premiums.
Lastly, although we have not attempted to estimate the energy savings potential associated with the farm layout, we would expect some reduction in total power consumption due to reduced fab area, reduced thermal and frictional losses associated with piping distribution, and a general consolidation of support systems. Savings areas might include energy to power systems such as abatement, PCW, UPW, fab lighting and FFUs.

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Personnel Safety

We discussed the significant safety improvement of the farm concept related to moving metrology and associated personnel outside the hazardous building area. Another safety improvement in the farmed fab lies in the reduction of facility piping distribution and joints. These reductions translate into improved overall reliability of toxic gas and chemical distribution systems.

Implications to Fab Design and Construction Schedule

One would expect the design and construction duration for a farm fab to be less than that of a hybrid fab for several reasons. The amount of building area and piping/ducting distribution are significantly reduced in the farm. Additonally, with distribution systems more tightly consolidated, overall space management is easier. Finally, tool installation is greatly simplified when tools are installed in predictable, repeating layout patterns. All of these factors contribute to reducing the overall design and construction schedule.

Conclusions

We have compared the costs of the farm layout concept to that of the hybrid, and have found significant savings opportunity, including a conservative estimate of a 6% reduction to the combined cost of AMHS and construction. Our basic examination of the factors affecting tool utilization and product cycle, demonstrates that these issues can be solved at relatively minor cost, by increasing the fab AMHS capacity. Finally, we have discussed various operational benefits of the farm layout, including the potential to reduce ongoing costs for manpower, insurance, and energy consumption.

Acknowledgments

Jim Arthurs, Peter Csatary, Manfred Engelhard, John Frank, Kevin Moss

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