

# **A Cost of Ownership (COO) Model**

for

## **Probe Cards**

INTERNATIONAL SEMATECH



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## **INTRODUCTION**

In recent years, probe cards have become increasingly more expensive and new alternative probe card technologies with unique cost, performance, and lifetime attributes have emerged. To enable an educated selection among probe card alternatives, the International SEMATECH Manufacturing Initiative (ISMI) Probe Council has developed a Probe Card Cost of Ownership Model for use by both ISMI member companies and probe card suppliers. The model reduces a multitude of complexly related factors involved in the probe card selection process to a single measure of value. Now it is simple to determine the values of alternative probe card technologies with respect to the process they will run.

The model incorporates two worksheets that allow the user to enter information about the production environment and the probe card alternatives. The model then presents information clearly showing the overall cost of ownership of each solution, a breakdown of the major expenses of each alternative, and the breakeven period for more expensive initial purchases.

To fully use the model, organizations need to understand their processes in terms of the elements of the model. These common elements provide a basis for further development. They could allow greater benchmarking among probe organizations and more effective sharing of information.

## **BACKGROUND**

The probe card is the final electrical connection between the tester and the device under test (DUT). In the past, cantilever was the only predominant probe card technology to select from. This as well as the relatively inexpensive cost of probe cards made decisions about ordering probe cards uncomplicated.

However, similar to DUT and TESTER trends, the increased complexity and performance required of probe cards have driven increases in card costs. Consequently, probe cards have become an expensive outlay. Moreover, in recent years, new alternative probe card technologies have emerged to rival cantilever technology. These new technologies each have unique cost, performance, and lifetime considerations. Thus, selecting the ideal probe card can significantly impact the cost of test.

## **ISMI COO OBJECTIVES**

Because the increased cost of probe cards along with technology considerations has complicated the selection of appropriate probe cards, ISMI has developed a COO model to

1. Make available a common tool with which members and suppliers can assess and share probe solution performance data in a transparent format.
2. Allow suppliers to present cost performance data to ISMI members reducing the initial, currently repetitive analysis effort expended by members.

## **Basic Concept**

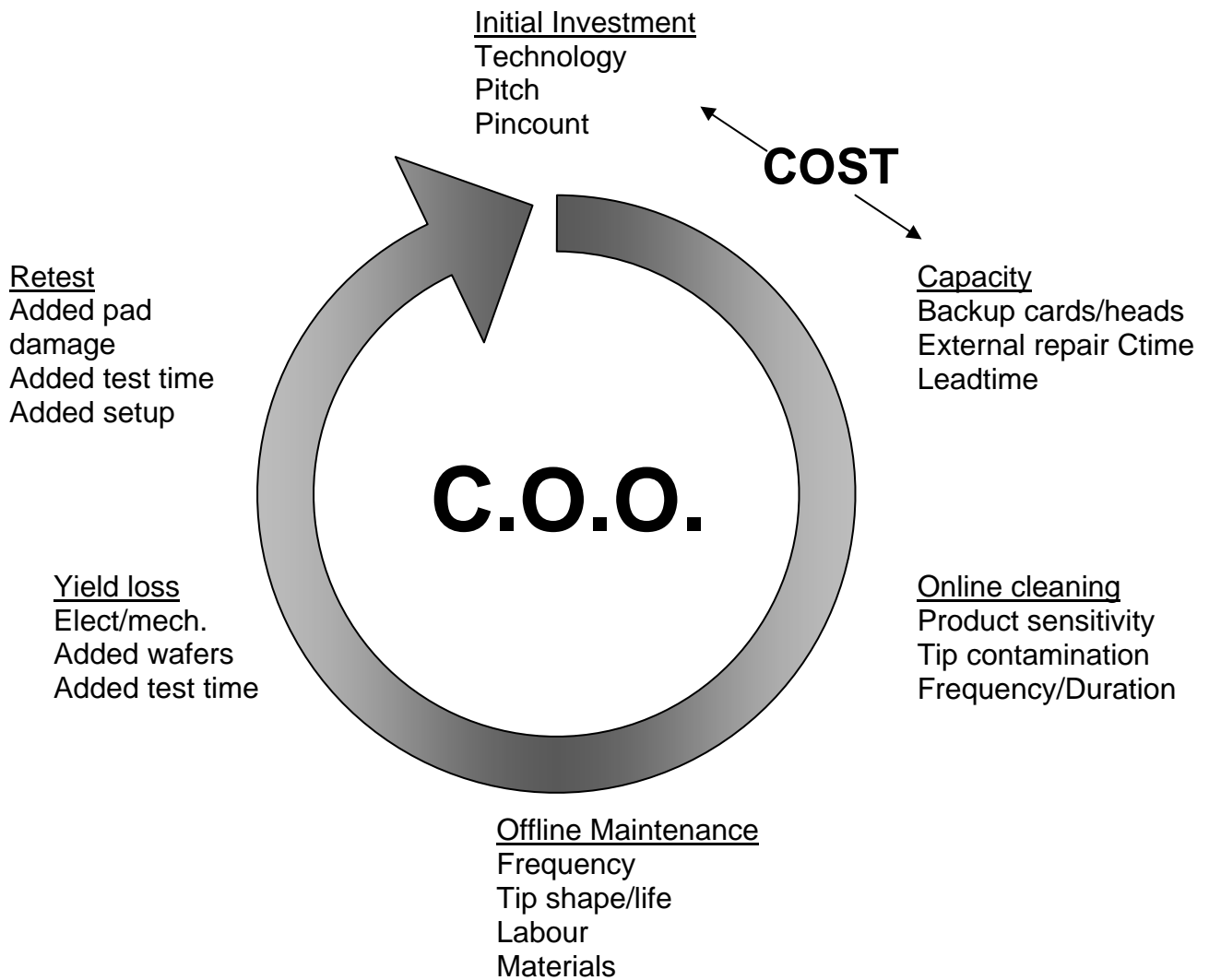
The basic assumption behind the probe card cost model is that an organization has a desire to sell a fixed amount of a product under study. For example, several factors affect the cost of producing 10,000,000 functional parts. The probe process can affect the amount of time, number of wafers, hardware, and support expenses required to meet the ultimate ship requirement. The choice of probe card can impact each of these factors.

The ISMI probe card COO model takes user inputs on probe card alternatives and estimates. Descriptions of each probe card are used to estimate the impact a probe card alternative will have on the probe process. These effects are then used to determine the overall cost of ownership of each probe card alternative.

# COO DESCRIPTION

The COO model is a spreadsheet-based tool that provides the following:

- Cost comparisons of different probe card solutions
- Quantification of the key contributing parameters
- Indication of the impact of varying demand volumes on an application-specific basis over the full product lifecycle

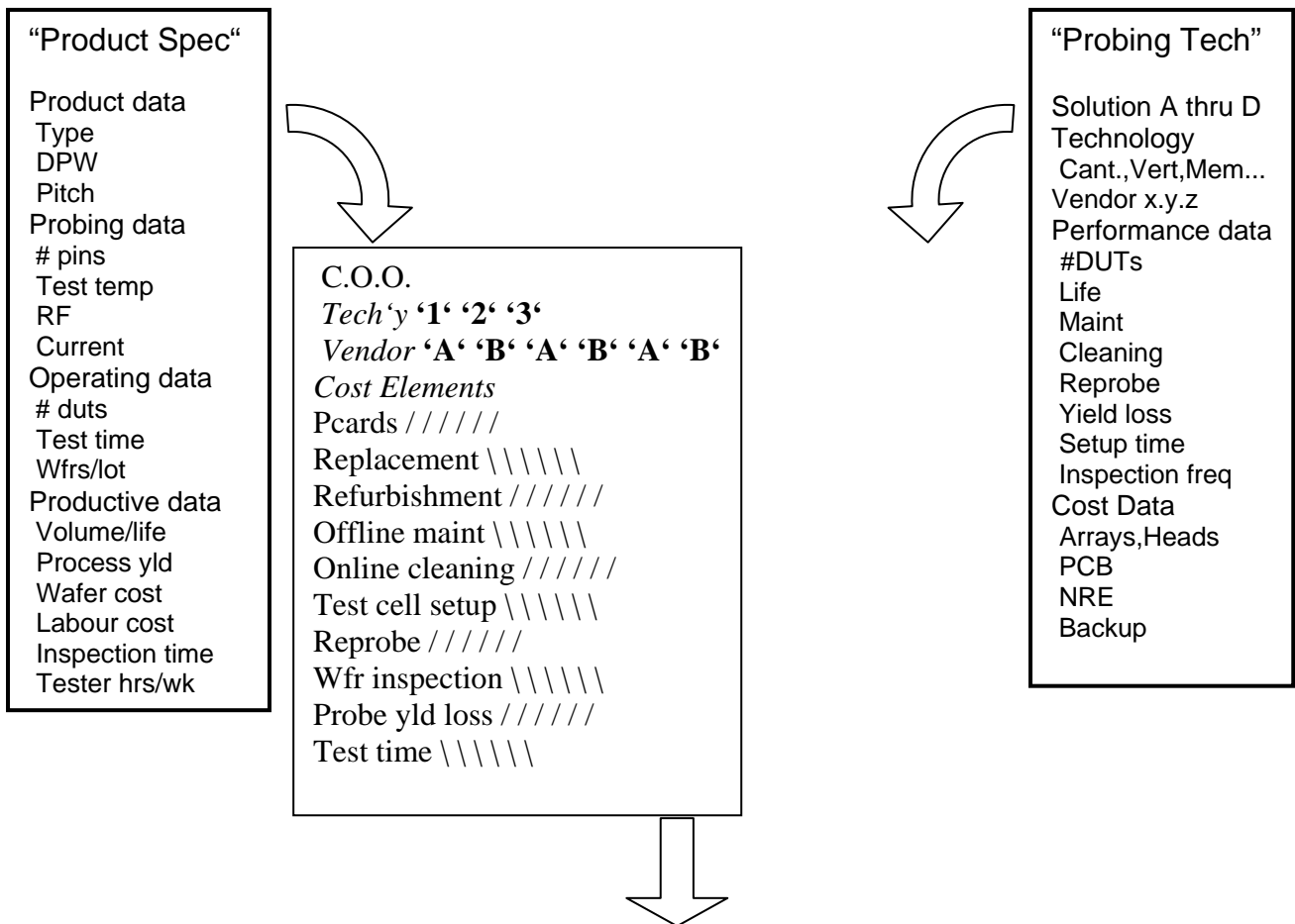


## NOTE:

Comments are attached to modules in the spreadsheet to help explain the use of the parameters and the basic formulae used in the COO model.

# COO MODEL STRUCTURE

The basic structure of the COO model is illustrated below. Product specifications and test considerations are combined with details specific to the probe card solutions. This information is used to estimate the overall cost of ownership for each probe card alternative.



<b>COO–xxx</b>	<b>= Cost element v volume for solution ‘xxx’</b>
<b>Total test cost</b>	<b>= Basic test time and PCard cost for each solution</b>
<b>Probe card. costs</b>	<b>= Cost element breakdown for each solution</b>
<b>Cost=f(Volume)</b>	<b>= Test cost per good die and PCard savings vs volume vs solution</b>

# Inputs

## PRODUCT SPECIFICATION

The first of two worksheets requiring user input is Product Specification, mainly consisting of operational data. Data entered in this worksheet provide information about the environment in which the probe card is used.

There are both required and optional fields. Required fields contain information to calculate the probe card COO. Optional fields contain information that may be useful for technical considerations. These fields are provided in the COO model as a convenient location to store all information relevant to selecting a probe card.

Parameter	Unit	Value	
<b>Product Specification</b>			
Internal Product Name	n/a	X1234	
# of Die per wafer	n/a	1500	
*Die length	mm		
*Die width	mm		
*Min. Pad pitch	µm		
<b>Probing Parameters</b>			
*# of pads contacted	-		
*Test temperature (Max)	°C		
*# of low speed RF lines (<3Ghz)	-		
*# of high speed RF lines (3 - 10 GHz)	-		
*Max. current per pin (continuous)	mA		
*Max. current per pin (peak)	mA		
*Bandwidth	MHz		
*No. of components req'd on the PC	-		
<b>Operating Data</b>			
* # of DUT's POSSIBLE (tester)	n/a		
Test time per Tdown for 1 dut testing	s	4,0	
# of wafers per lot	n/a	25	
<b>Planning Data</b>			
Wafer starts per week / duration "base load"	- / wks	10	15
Wafer starts per week / duration "ramp up"	- / wks	35	36
Wafer starts per week / duration "ramp down"	- / wks	20	25
Total product life cycle	weeks	76	
Total # of good die required	n/a	2.865.000	
<b>Productive Data</b>			
Expected yield	-	85%	
Cost of wafer (processing)	\$	2000	
Ave. # of probers per operator	n/a	5	
Operator labour cost	\$/hr	20,00	
Pcard technician labour cost	\$/hr	40,00	
Test(er) time cost	\$/sec	0,05	
Wafer inspection points per wfr sample	n/a	3	
Wafer inspection time per point	s	10,00	
Tester production availability	hrs/wk	120	

**NOTE:**

- Data must be entered for ALL blue parameters.
- Other parameters denoted with \* are relevant for the selection and costing of the probe solution.
- Default values are *not* embedded in the spreadsheet. Values shown are examples only.

**PROBING TECHNOLOGY**

The second section requiring user input captures information about probe card technology alternatives:

1. Pricing data
2. Probe card “spec/characterization” data supplied by the vendor and/or user available evaluation/production performance data.

**Special Procedures**

1. Select Probing Technology, Probe Card Vendor, and Vendor Model by *clicking on the appropriate cell, clicking on the down arrow, and making selection.*
2. Remove a solution from the assessment by selecting “n/a” under Probing Technology.
- 3.

Comments describing the parameters and where they are used are included in the Input and COO worksheets.

Solution		A	B	C	D	E	F
Probing Technology		Cantilever	Vertical	Membrane	n/a	n/a	n/a
Probe Card Vendor		A	B	C	n/a	n/a	n/a
Vendor Model		n/a	n/a	n/a	n/a	n/a	n/a
Parameter	Unit	Values					
Discounted Price per Probe Head		\$ 10,000.00	\$ 25,000.00	\$ 20,000.00	\$ -	\$ -	\$ -
PCB		\$ 5,000.00	\$ 5,000.00	\$ 5,000.00	\$ -	\$ -	\$ -
NRE Probe Head		\$ 2,000.00	\$ 5,000.00	\$ 7,000.00	\$ -	\$ -	\$ -
NRE PCB & Assembly		\$ 1,000.00	\$ 1,000.00	\$ 1,000.00	\$ -	\$ -	\$ -
Backup cost		\$ 15,000.00	\$ 25,000.00	\$ 20,000.00	\$ -	\$ -	\$ -
Parameter	Unit	Values					
# of DUT'S implemented	Xn	2	4	2	0	0	0
Test time per Touchdown for Xn	secs	4	5	4	0	0	0
"Contact/head" life (replace/rebuild)	# of T/downs	1,000,000	1,500,000	2,000,000	0	0	0
ONline cleaning frequency	# of T/downs	200	1000	1000000	0	0	0
ONline cleaning time	secs	25	25	25	0	0	0
OFFline maintenance frequency	# of T/downs	10,000	10,000	250,000	0	0	0
OFFline maint. time	minutes	75	75	60	0	0	0
OFFline maint. costs (mat/equipt)	\$	\$200	\$200	\$100	\$ -	\$ -	\$ -
"Contact" refurbishment frequency	# of T/downs	250,000	250,000	2,000,000	0	0	0
Refurbishment costs (mat/equipt)	\$	\$200	\$200	\$0	\$ -	\$ -	\$ -
Pcard mishandling damage	%	3,00%	3,00%	1,50%	0,00%	0,00%	0,00%
Retest (reprobe) Rate	%	2,00%	2,00%	1,00%	0,00%	0,00%	0,00%
Mech. yield loss (pad damage)	%	0,10%	0,10%	0,00%	0,00%	0,00%	0,00%
Elect. yield loss (Cres)	%	2,00%	0,50%	0,50%	0,00%	0,00%	0,00%
Pcard setup time (tester)	minutes	30,0	30,0	30,0	0,0	0,0	0,0
Post probe Wfr inspection rate	nth wafer	10	10	15	0	0	0
Max.util'n of base card qty(backup calc)	%	75%	75%	70%	0%	0%	0%
# of backup cards required	-	2	2	2	0	0	0

NOTE:

- Data must be entered for ALL parameters. If the user does not want to consider a parameter or values are unknown, equal values should be entered across all alternatives.
- Default values are *not* embedded in the spreadsheet. Values are shown as examples only.

For the model, probe card costs are divided into five categories:

*Discounted Price per Probe Head*

The cost of probe needles is considered separately from the cost of PCBs. This cost is defined as the probe head cost. If the technology uses interchangeable probe heads, this concept is intuitive. With fixed needle technologies such as cantilever, the cost of adding the needle ring must be differentiated from the cost of the circuit board.

*PCB Cost*

This is the cost of the printed circuit board, including components and fixtures to connect with the probe needle array.

*Backup Cost*

The cost of backup hardware is listed separately. For some technologies, this will be the cost of the probe head. For other technologies, it will be the cost of the needle array and the PCB. the COO model, backup hardware is reserved for a quick response to emergency situations. For example, if a probe head is damaged, a backup head will be used, but immediately replaced by a new backup component. Thus the number of backup components remains steady throughout the evaluation.

Non-recurring costs are absorbed into *NRE for Probe Head* and *NRE for PCB and Assembly*. Both of these costs are experienced only once during the first period of the model.

Probe card maintenance events occur at four different levels. Each event has an associated interval and expense. These events may be defined according to the individual organization or probe card technology requirements. For the general model, the levels of probe card maintenance are as follows:

**On-line Cleaning**

Most probe processes use an automatic probe needle cleaning. This clean is performed by the prober at a pre-defined interval, typically without user intervention. Expenses associated with on-line cleaning are usually test time expense and any consumable material used for the clean,

**Off-line Maintenance**

At some interval or under certain circumstances, most probe processes require regular maintenance on the probe card. Typically manual, this maintenance might be carried out by a Probe Card Repair (PCR) area. The expense of this operation typically includes operator time, metrology equipment time, and consumable components.

## Refurbishing

Occurring less frequently and costing more, refurbishing may include reshaping needle tips, minor rebuilds, replating needles, replacing components, etc. Expenses might include external expenses.

## Rebuild/Replace

This is the longest probe card maintenance event used by the model.

Rebuild/replace expenses usually include the replacement cost for an entire probe card or the wear components of a probe card.

# OUTPUTS

## COO-ALL

This spreadsheet contains the overall cost estimates for each probe card alternative. Costs are displayed in various categories, and some particularly interesting support data are presented as well.

The first few rows of the spreadsheet are dedicated to basic process information. The total number of die that must be probed is displayed followed by the weekly run rate necessary to meet this goal. This information is used to determine the base number of probe cards and testers needed to meet the required weekly capacity. Card utilization is then calculated as the percentage of the available probe card time used per week.

The following rows present basic information about the probe card purchase price for reference. This is followed by *Total initial investment*, the minimum cost to acquire production probe card and backup inventory to meet demand.

The next four major categories reflect the four levels of maintenance events. Each category shows the total expense throughout the evaluation period incurred by that type of maintenance. Additional useful information is presented along with each category that might be useful in choosing the most appropriate probe card.

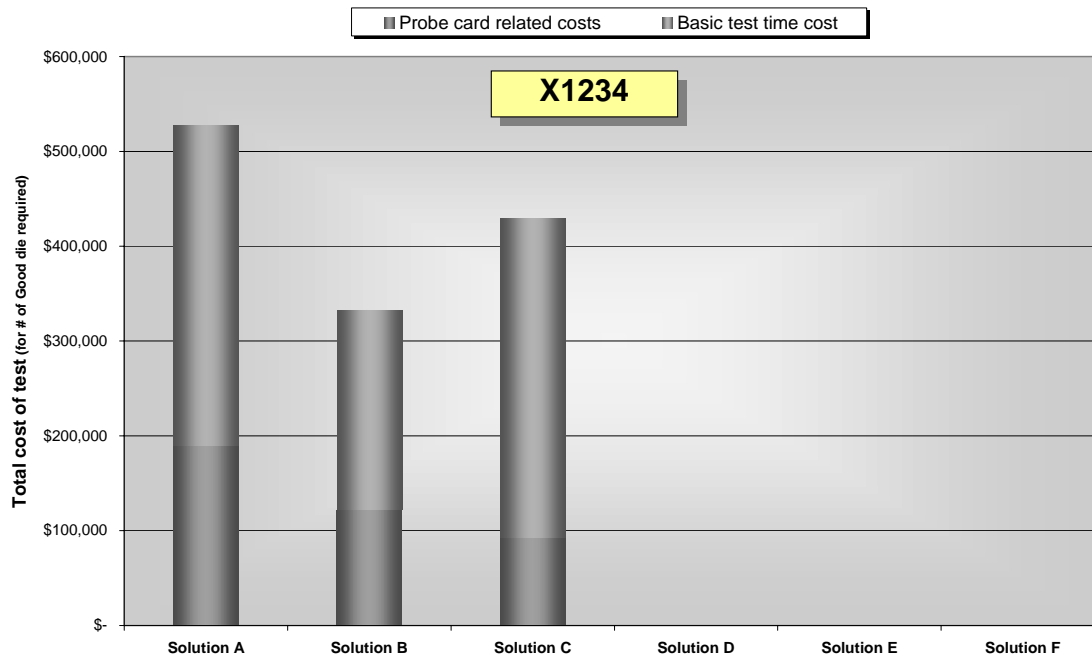
The following sections are dedicated to the cost of running the production process. The value of lost system time and labor associated with *Tester cell setup*, *reprobe*, and *wafer inspection* is presented.

Probing yield loss reflects the value of additional die required to make up for good die that fail because of probe card-related yield loss. This is followed by the value of the test time to probe all die to meet customer demands.

The individual categories are added together to determine the total cost of probe to meet customer demand for the evaluation period. This is then divided into an average cost per good die. This number represents the additional cost that the test process adds to the overall production cost of die sold.

## TOTAL TEST COSTS

The total test worksheet is a graph that contains a summary of the overall cost of each test alternative for the evaluation period.

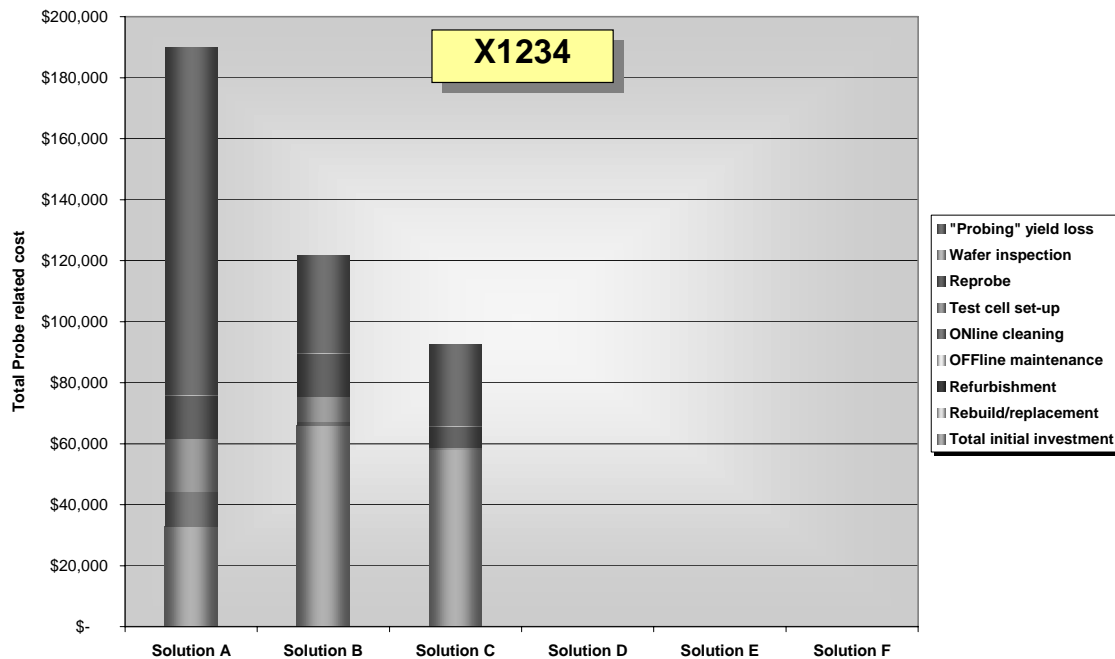


The cost is broken into two categories: *Basic Test Time Costs* and *Probe Card Related Costs*. Differences in *basic test time* reflect the savings in yield and process times of one technology over another. *Probe Card Related Costs* reflect maintenance and purchase expenses for each probe card alternative.

## PROBE RELATED COSTS

The graph below breaks down the probe card-related costs from the overall cost chart into smaller components.

Breakdown of Probe related test costs (for # of Good die required)



These more specific components provide insight into what process modifications might be useful in improving the COO of each alternative.

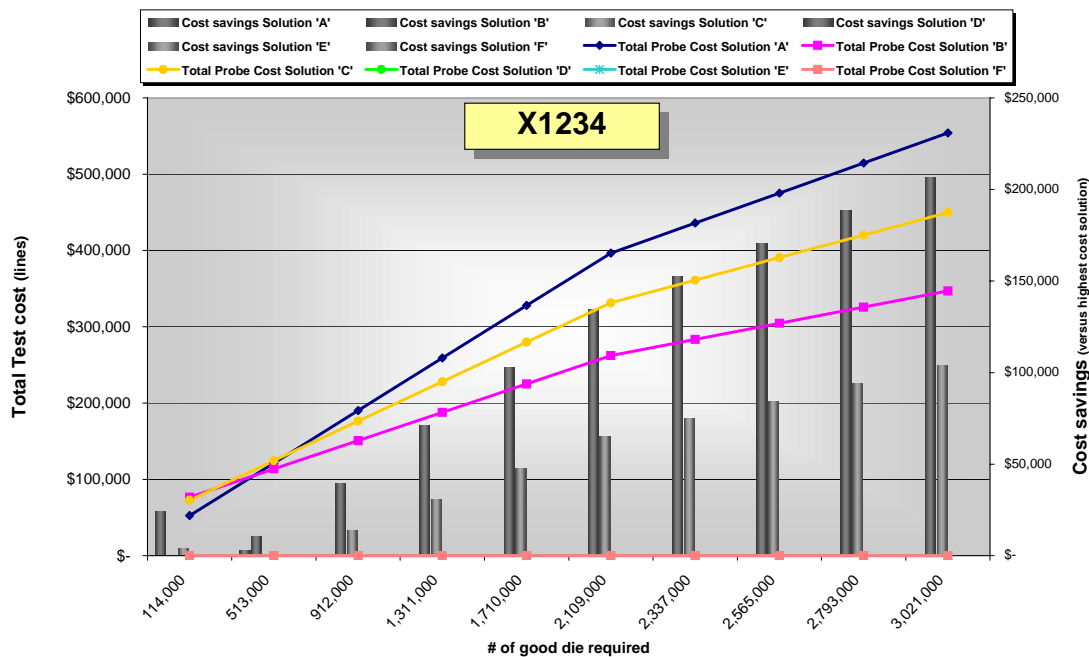
- Probe Yield Loss – Expense incurred by additional wafer production to replace die lost because of test-related issues
- Wafer Inspection – Expense of time spent on visual wafer inspections to ensure outgoing quality
- Re-probe – Expense of time spent retesting die to ensure test results are accurate
- Test cell setup – Expense of time spent performing tool changeovers or lot setups to keep a tool dedicated to the product running in production
- On-line Cleaning – Expense of test time during wafer probe to clean the probe card in situ
- Off-line Maintenance – Expense of time spent in off-line operations, such as PCR, to keep probe cards performing at desired levels
- Refurbishment – Expense of serious probe card maintenance events to extend the life of probe cards
- Rebuild/Replacement – Expense of old probe card replacement and rebuild to keep a desired probe card inventory level throughout the evaluation period
- Total Initial Investment – The portion of the overall cost to purchase probe cards to meet capacity requirements

## Cost per Period

This graph shows the overall cost of each probe card solution at the end of each time period. The graph can help determine the breakeven period for one alternative over another. Additionally, the rate of return can be seen from the slope of each line, and decisions based on the effects of volumes and timing may be considered.

The savings of alternatives to the most expensive solution for the period of time selected for the analysis are displayed in columns. The columns reveal specific savings for alternatives.

The X-axis shows the total number of good parts required before the end of each time period.



## Per Good Die Cost

This graph is very similar to the overall cost graph, but provides an interesting perspective.

The lines indicate the probe costs per good die for each of the probe card alternatives. The graph can be used to determine the portion of the die sale price that is consumed by the probe process. For probe cards with high initial costs but lower sustaining costs, the cost per good die diminishes as volume increases.

The column chart indicates the overall savings at the end of a period projected by selecting an alternative to the highest cost solution.

