Test Strategy Working Group
Project 3 – Test Cost Model

Test Strategy Project 3
Test Cost Model
April 1, 2003
Project 3 - Introduction

“It is believed that an economic model is an important part of the Test Strategy Working Group investigation in order to help communicate the potential need and benefits of automated inspection and test methods”.

Project 3 Objective:

To develop a simple test strategy cost modeling tool that could be used to define a manufacturing PCA test strategy by estimating the cost of finding and repairing manufacturing assembly defects using various types of test and inspection strategies. This economic model would help communicate the potential needs and benefits of each test technique and would help users understand the impact of removing test stages vs. sampling strategies vs. 100% inspection or test methods.

Connect with and Strengthen Your Supply Chain
• 6 participant companies represented in group 3:
  – Teradyne, Inc. (Amit Verma)
  – Agilent Technologies, Inc. (Stig Oresjo)
  – Solectron, Inc. (David Mendez, Nga Nguyen)
  – Delphi Electronics, Inc. (Brian Chandler)
  – Hewlett-Packard Company (Rosa Reinosa, Carlos Michel)
  – Intel Corporation (James Grealish)

• All project 3 participant companies shared their test cost models and ROI best practices.

• Analysis of each of the tools presented focusing on:
  – Key Drivers
  – Assumptions
  – Likes/Dislikes.
Test Cost Model development process

- Agreement of all group 3 participants on the inputs and outputs that the NEMI test cost model would have - The voting list.

  - Define default inputs and outputs.
  - Each company voted on desired inputs and outputs.
  - Inputs and outputs with majority of votes to be included in the test cost model.
Test Cost Model development process

• Development of the Test Cost Model tool
  – Utilizing the best concepts and formulas of each of the presented models and including the inputs and outputs selected (voting list) by the group.
  – Conference calls (each other week) with all group 3 participants to revise the progress of the tool development and to provide feedback.

• Recurrent Activities
  – Release of a new version of the test cost model
  – All participant companies to review the new version of the test cost model and provide feedback.

This recurrent process went on until the release of the final version of the test cost model (Rev H) on October 2002. The development of the tool lasted one year.

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Team decided to release the test cost model to the public domain after APEX 2003 in order to:

- Allow participant companies to utilize the test cost model before public release as a competitive advantage.
- Perform tool validation.

The NEMI Test Strategy Working Group decided that the test cost model would be released after APEX with minimum restrictions. It was decided, however, that the test cost model should be password protected and copyrighted only to prevent others to use the model for commercial purposes.

The Test Strategy Cost Model is being copyrighted only by the Project 3 participating companies.
Objective: To develop a PCA manufacturing test strategy cost model that will enable a company to determine the financial impact of selecting a particular test strategy.

• What do we hope to accomplish with the test cost model?
  – Enable a company to estimate the ROI on a particular manufacturing test strategy.
  – Make tradeoff analysis and decisions based in the financial impact that a strategy may have on an organization.
  – Provide visibility to decide key test strategy drivers.

• What is expected of industry adoption?
  – Adopt this test strategy cost model as a standard tool to determine the financial impact of selecting a particular test strategy.
  – Would like for companies to select this tool as their tool of choice to drive test strategy decisions.
  – Drive standardization of the economic analysis of test strategies.
The NEMI Test Strategy Cost Model has the ability to compare two different PCA test strategies and provide the strategies cost, yield enhancement savings, defects escaping out of the strategy, DPMOs/yield for each test stage, ROI metrics and time to market savings. The model uses a spreadsheet format and is intended for post-reflow PCA test strategies:

The following variables were considered in the model:

- Programming Cost
- Equipment Cost
- Fixture Cost
- Maintenance Cost
- Test operators Cost
- Scrap Cost
- Re-test (false rejects) Cost
- Repair & Diagnostics Cost
- Field Return Cost

The following metrics were considered on the ROI analysis in the model:

- Investment
- Payback
- Net Present Value
- Internal Rate of Return

The following investments were considered on the Time To Market analysis in the model:

- R & D revenue
- COGS
- Sales and Marketing
- General and Administrative

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The NEMI Test Strategy Cost Model is divided in 4 sections:

- Overview Section.
- Inputs Section.
- Defaults Section.
- Outputs Section.
Overview Section. This section contains a high level description of the test cost model, the copyright disclaimer and the names of the companies and the participants in the development of the tool.

OBJECTIVE

The objective of the Inspection and Test Strategy Cost Model is to enable a user to understand the financial impact of selecting a manufacturing test strategy. The model uses a spreadsheet format and is intended for post-reflow PCA test strategies.

ACKNOWLEDGEMENTS

We would like to thank the following individuals for their contributions and participation:

- Amit Verma ------ Teradyne
- Stig Oresjo ------ Agilent
- James Grealish ------ Intel
- Nga Nguyen ------ Solectron
- David Mendez ------ Solectron
- Brian Chandler ------ Delphi Delco
- Rosa Reinosa ------ Hewlett-Packard
- Carlos Michel ------ Hewlett-Packard
**Inputs Section.** This is the section where the users need to enter all the information related with their PCA and their test strategies, up to 50 inputs are required to be completed in this section.

**Test Strategies Inputs**

- **Strategy 1 Types of Test/Inspection**
  - Field Return Rate: 1 [Default]
  - Number of test/inspection stages on Strategy 1: 2
  - Stage 1 (Name): ICT
  - Stage 2 (Name): FT
  - Stage 3 (Name): 
  - Stage 4 (Name): 

- **Strategy 2 Types of Test/Inspection**
  - Number of test/inspection stages on Strategy 2: 3
  - Stage 1 (Name): AXI
  - Stage 2 (Name): ICT
  - Stage 3 (Name): FT
  - Stage 4 (Name): 

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Defaults Section. This section provides a default value for each of the inputs on the inputs section, if an input is unknown to the user, he or she can select a value for that particular input from the defaults section. These defaults values are based on medium-high complex board manufactured in US.
**Outputs Section.** This is the section where the test cost model results are presented to the user. It contains a strategy flow of both strategies with the DPMO/yield data of each of the test stages and the defects escaping out of the test stages and out of the strategy, a summary and a graphical cost comparison of the strategies, a section for the ROI metrics and the results of the Time To Market calculations.

<table>
<thead>
<tr>
<th>Test Strategy 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Defects</strong></td>
</tr>
<tr>
<td>21,765.60</td>
</tr>
<tr>
<td>Defects after ICT</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test Strategy 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Defects</strong></td>
</tr>
<tr>
<td>21,705.88</td>
</tr>
<tr>
<td>Defects after AXI</td>
</tr>
</tbody>
</table>
Summary and graphical cost comparison of both strategies

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## ROI metrics and Time To Market Savings

### ROI JUSTIFICATION

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
<td>$460,000</td>
</tr>
<tr>
<td>Payback (years)</td>
<td>0.39</td>
</tr>
<tr>
<td>Net Present Value</td>
<td>$3,515,360</td>
</tr>
<tr>
<td>Internal Return Rate</td>
<td>217%</td>
</tr>
</tbody>
</table>

### TIME TO MARKET SAVINGS

#### Planned Schedule vs. Early Schedule

<table>
<thead>
<tr>
<th>Product &amp; Investment Inputs</th>
<th>Planned Schedule</th>
<th>Early Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned Product Life Time</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Target Sales Price</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>R&amp;D Percentage of Revenue</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>COGS Percentage of Revenue</td>
<td>45%</td>
<td>45%</td>
</tr>
<tr>
<td>S&amp;M Percentage of Revenue</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>G&amp;A Percentage of Revenue</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Profit</td>
<td>10%</td>
<td>10%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Planned Schedule</th>
<th>Early Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to reach peak sales</td>
<td>6</td>
</tr>
<tr>
<td>Peak Sales during maturity</td>
<td>1000</td>
</tr>
<tr>
<td>Time for decline period</td>
<td>6</td>
</tr>
</tbody>
</table>

#### Savings with early Introduction:

- **$6,440,000**
- **Yearly Savings:** **$2,160,000**

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**Connect with and Strengthen Your Supply Chain**
A user’s guide was developed to help the users of the model to understand the capabilities of the tool and to learn how to utilize the test cost model. The user’s guide is a document with 72 pages of text and images that describes in detail each one of the sections of the test cost model and explains, step by step, how to enter all the required information into the model and how to interpret the results on the outputs section. This user’s guide contains also a section called **calculations section** that explains in detail all the formulas used in the test cost model.
The present tool models test coverage of each test stage in multi-stage test such that test coverage always overlaps from one stage to another. This model will not accurately represent results when multiple test stages are used in a complementary manner.
In a test process there are true failures and false failures. When we have a diagnostic process, the following things can happen with the failures detected at a particular test station:

1. A true failure diagnosed as a true failure.
2. A true failure diagnosed as a false failure.
3. A false failure diagnosed as a true failure.
4. A false failure diagnosed as a false failure.

In this test cost model we are assuming a 100% diagnostic yield, which means that the diagnostic is always accurate. In other words, in the present tool we are only considering cases 1 and 4.

The economic impact of the false failures (case 4) is reflected on the test cost model in the calculation of the diagnostic and re-test costs.

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Test Cost Model Example

Objective: Identify what benefit (if any) would have the addition of Automated X-Ray inspection to a current test strategy.

• Current Test Strategy (Strategy 1) has 2 test stages: ICT and FT.

• Proposed Test Strategy (Strategy 2) has 3 test stages: AXI, ICT and FT.

<table>
<thead>
<tr>
<th></th>
<th>AXI</th>
<th>ICT</th>
<th>FT</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Test Effectiveness [%]:</td>
<td>90.00%</td>
<td>80.00%</td>
</tr>
<tr>
<td>29</td>
<td>Test Access Multiplier:</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>30</td>
<td>Test Time [min]:</td>
<td>3.00</td>
<td>1.00</td>
</tr>
<tr>
<td>31</td>
<td>False Reject Units:</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>32</td>
<td>False Reject Rate:</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>33</td>
<td>Number of Test Operators:</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>34</td>
<td>Annual Test Operator Cost (per operator) [$]:</td>
<td>$28,000</td>
<td>$35,000</td>
</tr>
<tr>
<td>35</td>
<td>Repair feedback loop [1 or 0]:</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>36</td>
<td>Repair Yield [%]:</td>
<td>90.00%</td>
<td>90.00%</td>
</tr>
<tr>
<td>37</td>
<td>Re-test Cycles Permitted:</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>38</td>
<td>Repair Cost [$/per defect]:</td>
<td>$1.00</td>
<td>$1.00</td>
</tr>
<tr>
<td>39</td>
<td>Diagnostic of Defects Cost [$/per defect]:</td>
<td>$1.00</td>
<td>$5.00</td>
</tr>
<tr>
<td>40</td>
<td>Equipment Cost [$]:</td>
<td>$450,000</td>
<td>$500,000</td>
</tr>
<tr>
<td>41</td>
<td>Fixture Cost [$]:</td>
<td>$0</td>
<td>$20,000</td>
</tr>
<tr>
<td>42</td>
<td>Programming Cost [$]:</td>
<td>$10,000</td>
<td>$30,000</td>
</tr>
<tr>
<td>43</td>
<td>Annual Maintenance Cost [$]:</td>
<td>$25,000</td>
<td>$20,000</td>
</tr>
<tr>
<td>44</td>
<td>Equipment Depreciation (years):</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

1. Annual Production Volume [boards/year]: 72,000
2. Board (PCA) cost [$]: $1,000.00
3. Field Return Cost [$/per board]: $1,500.00

Yield at 1st stage of strategy 1: 85.00%
Number of packages on board: 1,000
Number of Joints on board: 10,000

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>Strategy # 1</th>
<th>Strategy # 2</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Cost:</td>
<td>$400,000</td>
<td>$613,000</td>
<td>-$213,000</td>
</tr>
<tr>
<td>Yield Enhancement Savings:</td>
<td>$909,760</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Savings with Strategy 2:</td>
<td>$696,760</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Test Cost Model Next Steps

• The test strategy cost model will be posted on the “NEMI Test Strategy Project” webpage: http://www.nemi.org/projects/ba/test_strat.html The model will be in Excel file format and will be downloadable.

• Feedback and comments about the NEMI Test Strategy Cost Model will be received at the following e-mail address: costmodel@nemi.org