True Cost-of-Test for SSD High Volume Manufacturing and Large Scale Quality and Reliability Organizations

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Advantest America, Inc.

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MKW Ventures
A different perspective on Testing

At a glance

Founded: 1954, Tokyo Japan
Sales: ¥ 163.3B (~$1.5B)
No. of employees: 4,600
R&D Spending: ¥29.9B (~$250M)

Worldwide Presence

Europe
3 R&D Sites (Germany),
10 Sales/Support Sites
Total 700 employees

North America
3 R&D Sites (USA), 11 Sales/Support Sites,
1 Production Site
Total 500 employees

Japan
Advantest Headquarters (Tokyo)
4 R&D Sites, 5 Sales/Support Sites,
3 Production Sites
Total 2,500 employees

Asia Pacific
3 R&D Site (China, Singapore, India),
19 Sales/Support Sites, 3 Production Sites
Total 900 employees

Businesses

Semiconductor Test
Mechatronics
SSD Test
Services, Support & Others
Which SSD is Better?

OR
Which SSD Tester is Better?

OR
COT vs TCO definitions

- COT = purchase price of tester / throughput
- TCO = COT + Costs of Operation

“When choosing among alternatives in a purchasing decision, buyers should look not just at an item's short-term price, which is its purchase price, but also at its long-term price, which is its total cost of ownership.”

– Investopedia on the definition of TCO
Price vs COT vs TCO Analysis
## Throughput Impact on COT

### Simple COT model

<table>
<thead>
<tr>
<th></th>
<th>Tester A</th>
<th>Tester B</th>
</tr>
</thead>
<tbody>
<tr>
<td>a-1</td>
<td>Tester price [hypothetical]</td>
<td>$500,000</td>
</tr>
<tr>
<td>a</td>
<td>Tester cost per hour</td>
<td>$11.42</td>
</tr>
<tr>
<td>b</td>
<td>5 year depreciation</td>
<td></td>
</tr>
<tr>
<td>c-1</td>
<td>Baseline test time [h]</td>
<td>10</td>
</tr>
<tr>
<td>c-2</td>
<td>Performance improvement</td>
<td>100%</td>
</tr>
<tr>
<td>c</td>
<td>Effective test time [h]</td>
<td>10</td>
</tr>
<tr>
<td>d</td>
<td>Utilization</td>
<td>80%</td>
</tr>
<tr>
<td>e</td>
<td>Test cell UPH (Units Per Hour) (= b \times c / d)</td>
<td>40</td>
</tr>
<tr>
<td>f</td>
<td>Cost per DUT (= a / e)</td>
<td>$0.29</td>
</tr>
<tr>
<td>f</td>
<td>COT reduction</td>
<td>0%</td>
</tr>
</tbody>
</table>

### Equipment cost to test ~3M units / year

<table>
<thead>
<tr>
<th></th>
<th>Tester A</th>
<th>Tester B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units per tester per year</td>
<td>350400</td>
<td>700800</td>
</tr>
<tr>
<td># of testers for 2.8M units / year</td>
<td>7.99</td>
<td>4.00</td>
</tr>
<tr>
<td># of testers purchased</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Tester investment</td>
<td>$4,000,000</td>
<td>$3,000,000</td>
</tr>
</tbody>
</table>
PCIe Multi-site Efficiency

7-day JESD219 Workload Run
Eight PCIe Gen 2 8-lane DUTs in parallel, measure average IO/s & MB/s per DUT

- Total IO/s per DUT @ 8 DUT parallelism
- Total MB/s per DUT @ 8 DUT parallelism

* Measured on Advantest MPT3000 w/ Full Accelerator
# Simple TCO Analysis

<table>
<thead>
<tr>
<th></th>
<th>Tester A</th>
<th>Tester B</th>
</tr>
</thead>
<tbody>
<tr>
<td>a-1</td>
<td>Tester price [hypothetical]</td>
<td>$500,000</td>
</tr>
<tr>
<td>a-2</td>
<td># of testers for 2.8M units / year</td>
<td>8</td>
</tr>
<tr>
<td>a-3</td>
<td>Total test cell price = a-1 * a-2</td>
<td>$4,000,000</td>
</tr>
<tr>
<td>a</td>
<td>Test cell cost per hour</td>
<td>$91.32</td>
</tr>
<tr>
<td>b-1</td>
<td>Consumables [cables, load boards] per Tester</td>
<td>$100,000</td>
</tr>
<tr>
<td>b-2</td>
<td>Total consumable costs = a-2 * b-1</td>
<td>$800,000</td>
</tr>
<tr>
<td>b</td>
<td>Consumable hourly cost</td>
<td>$91.32</td>
</tr>
<tr>
<td>c-1</td>
<td>Power consumption [tester - hypothetical]</td>
<td>6.4 kVA</td>
</tr>
<tr>
<td>c-2</td>
<td>Power per hour</td>
<td>$0.96</td>
</tr>
<tr>
<td>c-3</td>
<td>Floor space [hypothetical]</td>
<td>20 m²</td>
</tr>
<tr>
<td>c-4</td>
<td>Floor space cost per hour</td>
<td>$1.64</td>
</tr>
<tr>
<td>c-5</td>
<td>Operator cost per hour</td>
<td>$4.80</td>
</tr>
<tr>
<td>d</td>
<td>Estimated hourly cost = a + b + c</td>
<td>$241.88</td>
</tr>
<tr>
<td>e-1</td>
<td>Per Tester Parallelism</td>
<td>500 DUTs</td>
</tr>
<tr>
<td>e</td>
<td>Total Parallelism = a-2 * e-1</td>
<td>4000 DUTs</td>
</tr>
<tr>
<td>f-1</td>
<td>Baseline test time [h]</td>
<td>10 h</td>
</tr>
<tr>
<td>f-2</td>
<td>Performance improvement</td>
<td>100%</td>
</tr>
<tr>
<td>f</td>
<td>Effective test time [h]</td>
<td>10 h</td>
</tr>
<tr>
<td>g</td>
<td>Utilization</td>
<td>80%</td>
</tr>
<tr>
<td>h</td>
<td>Test cell UPH</td>
<td>320</td>
</tr>
<tr>
<td>i</td>
<td>Cost per DUT = f/j</td>
<td>$0.76</td>
</tr>
<tr>
<td>TCO reduction</td>
<td>0%</td>
<td>45%</td>
</tr>
</tbody>
</table>

## Additional Factors

- **Per Tester Operational Costs**
  - Consumable costs
  - Power costs
  - Floor space costs
  - Operator Costs
- **Number of Testers to test 2.8M units / year**

**Throughput Impact on TCO**

- 2x performance = 2x throughput
- 2x throughput = 50% less testers at same UPH
- 50% less testers = 50% less operational cost
- TCO reduction improves to 45%
### Other TCO considerations

<table>
<thead>
<tr>
<th></th>
<th>QUAL</th>
<th>HVM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Testing</strong></td>
<td>Very Long Test Times</td>
<td>Short to Long Test Times</td>
</tr>
<tr>
<td></td>
<td>More Capability / Cost</td>
<td>Cost Sensitive / Less Capability</td>
</tr>
<tr>
<td><strong>Service &amp; Support</strong></td>
<td>High Volume Manufacturing experience</td>
<td>Worldwide footprint</td>
</tr>
<tr>
<td></td>
<td>Additional services, e.g. test program, design services, etc.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contact 5dx8h, next day onsite</td>
<td>Same or better than QUAL</td>
</tr>
<tr>
<td></td>
<td>Spares: Regional</td>
<td>Spares: Local or onsite</td>
</tr>
<tr>
<td><strong>Financial Stability</strong></td>
<td>Important</td>
<td>Very Important</td>
</tr>
<tr>
<td></td>
<td>Resources / Scale to meet customer ramp(s)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ongoing investment in R&amp;D</td>
<td></td>
</tr>
<tr>
<td><strong>Roadmap</strong></td>
<td>Next gen challenges: PCIe 4, device handling &amp; shop floor automation</td>
<td>Protecting investment: Flexibility, Compatibility</td>
</tr>
<tr>
<td></td>
<td>Lead test innovation, drive COT reduction</td>
<td></td>
</tr>
</tbody>
</table>
Product Mix Impact on TCO

Market Demand A
- PCle
- SAS
- PCle
- SAS
- PCle
- SAS

Market Demand B
- PCle
- PCle
- SAS
- PCle
- SAS
- PCle
- SAS

PC Based
- PCle
- SAS
- PCle
- SAS
- PCle
- SAS

Reconfigurable
- PCle
- SAS
- PCle
- SAS
- PCle
- SAS

PC Based
- PCle
- SAS
- PCle
- SAS
- PCle
- SAS

Reconfigurable
- PCle
- SAS
- PCle
- SAS

No new testers, FW download in minutes

1x New Tester
1x Idle Tester
Bringing Semi OSAT model to SSD

**Semiconductor Test Model**

- Fabless Company A
- Fabless Company B
- Fabless Company C

**Avoid Capital Cost in Test Strategy**

- Avoid buy & consign
- Testers usable for different customers

**Standardized Testing**

- 90% standard, 10% custom
- True multi-protocol support in a single tester
- Standard functions + custom CMD hooks

**New Class of Tester**

- New! SSD Test Model
- SSD Company A
- SSD Company B
- SSD Company C

**OSAT buys Testers**

- Testers usable for different customers
- Avoid buy & consign

**Upside Flexibility**

- Scale out 10x, downside Flexibility

**High Volume Out-Source Assembly & Test (OSAT)**
Subcon TCO perspective

Test factories need to manage all items going into cost

• Floor space requirements, cost, and future needs
• Power: both power cost and supply/distribution needs
• Direct labor: managing testers, product flow, QA
• Indirect Labor: Managing factory floor, capacity, lead times, demand
• Engineering: Deploying new test solutions, validation, ECOs
• Overhead: IT, Support labs, HR, Management

Maximizing Utilization and optimizing the factory minimizes cost to OEM.
Value of Subcon Model

• Capital spending is minimized/eliminated by OEM
  • Customer pays for testing as it is needed, sees quick return in revenue or product results. No need to be perfect with prediction

• Subcon can flex test capacity to and from other applications minimizing cost
  • Upside capability can be planned for and reviewed, but not billed until use.
  • Costs of underutilization are minimized (ex: 50% loading=2x Cost)

• Pricing/volume models can include total flexibility, % minimum use, or capped capacity to meet OEM requirements for growth and cost

• Subcon manages factory space, staffing, capital purchasing, lead times

• Test hardware suppliers providing leading edge capability that meets latest requirements and testing standards. Proven solutions

• OEM Focuses on product health and business needs
Summary

- Equipment “Price Only” analysis is flawed

- HVM and Large Scale Quality and Reliability Organizations evaluate Total Cost of Ownership (TCO)
  → Equipment and Operational Costs, Throughput, Utilization need to be factored in

- New SSD Out-Source Assembly & Test (OSAT) model enables Test Capacity access and scale out flexibility to OEMs without having to justify Capital Equipment in their test strategies

Come visit our FMS booth #608 for a MPT3000 demo
Press Release: Advantest Expands MPT3000 System’s Capabilities in SSD Testing with Downloadable Firmware to Support Additional Protocols

MPT3000 Platform Becomes the Storage Industry’s Most Flexible and Extendible Test Solution for SSDs

TOKYO, Japan – August 3, 2015 – Leading semiconductor test equipment supplier Advantest Corporation (TSE: 6857, NYSE: ATE) has made available to customers downloadable firmware that enables all MPT3000 systems to test Serial Attached SCSI (SAS) 12G and Serial ATA (SATA) 6G solid-state drives (SSDs), making this tester the first true single-system solution for testing SAS, SATA and PCIe protocol SSDs.
Acronyms

- CMD = Command
- COT = Cost Of Test
- DUT = Device Under Test
- DWPD = Drive Writes Per Day
- GB (gigabyte) = 1000 MB (megabyte)
- HVM = High Volume Manufacturing
- JESD219 = JEDEC Enterprise Workload
- MTBF = Mean Time Between Failure
- OEM = Original Equipment Manufacturer
- OSAT = Out-Source Assembly and Test
- PB (petabyte) = 1000 TB
- QA = Quality Assurance
- QUAL = Qualification
- SW = Software
- TB (terabyte) = 1000 GB
- TBW = Tera Bytes Written
- TCO = Total Cost of Ownership
- TP = Test Program
- UPH = Unit Per Hour
- WW = Worldwide