SWTEST

PROBE TODAY, FOR TOMORROW

2022 CONFERENCE

Cost of Ownership (COO) Challenges & Score Card

TECHNOPROBE

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Cost of Ownership (COO) & Score Card

Presentation Overview

- Goal/Objective & background on Cost of Ownership (COO)
  - What are the external factors driving up COO?
  - How has COO been examined in the past?
  - Which major parameters are driving up COO?
  - Review of COO parameters across various categories
  - Examination of a comprehensive score card
  - Summary
  - Question & Answer: 5 minutes

Cost of Ownership (COO) & Score Card

Goal and Objective of the COO

- The Goal: Obtain the best test data & highest yield possible while effectively managing the cost of ownership

- The Objective: Apply a score card method to:
  - Understand the contributing COO components
  - Interpret and communicate the data effectively
  - Implement change to help reduce cost without sacrificing throughput or revenue
  - Manage the emerging supply chain

Cost of Ownership (COO) & Score Card

Background on the Cost of Ownership (COO)

Present subject in greater detail along with factors that contribute to COO

- **Today's leaders and managers want data driven concise answers**
  - **Answers that are developed with deep analysis that are the result of precisely targeted and sometimes complex queries on data sets**
- **Just like the field of Economics our understanding of COO has advanced**
- **Relational databases have provided the ability to easily find correlations**
- **Therefore the simple back of the envelop calculations no longer suffice**
- **Effective analysis of data trends / excursions requires a team of subject experts**
- **S/W tools allow operations team to monitor a wider range of parameters**

Cost of Ownership (COO) & Score Card

How has COO been examined in the past?

- The original purchase price has typically been the main driver of COO
- Where users seek the lowest price rather than cost per TouchDown (TD)
- Focus is placed on top parameters w/o knowledge of the complete cost
- Many factors contributing to the COO and product revenue are ignored
- Applying cost reduction across business areas without COO details
- Pounding a drum beat of lower unit cost to the supply chain managers

Note: Presentation provides opportunity to apply new COO score card tool

Cost of Ownership (COO) & Score Card

What are some of the external factors driving up COO?

- The past 2 ½ years have taught us to expect the unexpected
- Made us acutely aware of global competition for goods
- Meanwhile our marketplace has been experiencing yoyo growth
- Simultaneously we have been enduring supply chain constraints
- Recent world events have only exacerbated the supply chain issues
- Causing corporations and governments to focus more on risk management
- Rather than on the previous approach of seeking the lowest cost provider
- The new COO mantra for 2022 is risk mitigation and aversion
- While in parallel we seek to achieve the highest level of test capability

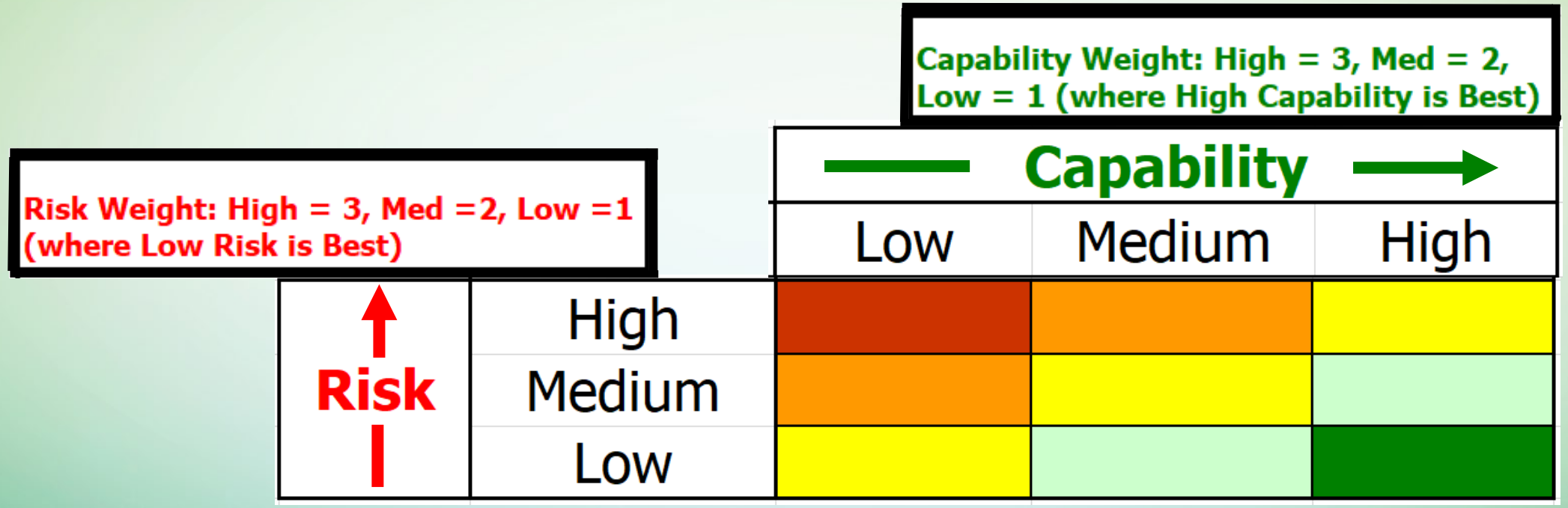
Cost of Ownership (COO) & Score Card

Other means of lowering COO at the test operation

- Automation is key to real-time monitoring of the test operation
- Open communication between operations and internal supply chain
- Establishing control limits to capture “Non-Happy Path” scenarios
- Distinguishing between commodity types within the supply chain
- Establishing an asset’s importance to corporate revenue generation
- Differentiating between printer paper and probing solution is critical
- Provide operations with an escalation path to purchasing agent
- Provide ability to adjust minimum stocking levels to trigger reorder
- Adjust # of units in shipment size being returned for repair/rebuild

Cost of Ownership (COO) & Score Card

To achieve the COO goal, we applied a method of assessing risk versus the probing solution capability for the test operation



<u>Take Away:</u> The goal is to minimize risk and maximize capability

Cost of Ownership (COO) & Score Card

Which parameters typically drive up probing COO?

- **Initial cost of probing solution might only be 50% to 70%**
- **Other factors which make up the balance of COO**

✓ **Poor incoming quality**

✓ **Complexity of maintenance / repairs**

✓ **Level of abuse experienced by the probing solution**

✓ **Number of probing solution units in the supply chain**

✓ **Amount of usable probe tip length until end-of-life**

✓ **Cost required to rebuild the probing solution(s)**

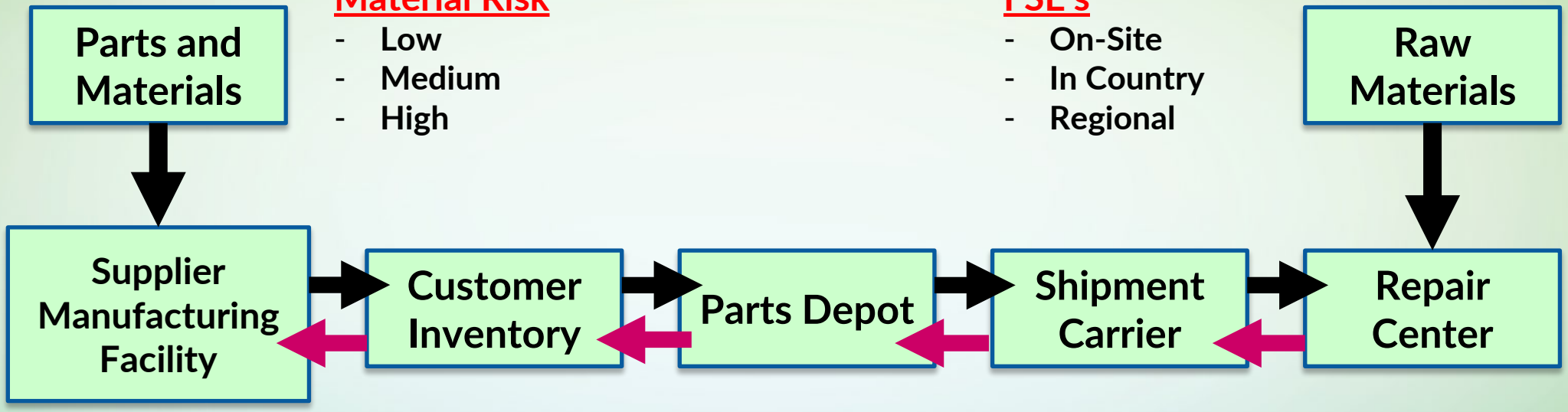
Cost of Ownership (COO) & Score Card

Which parameters typically drive up probing COO? – cont'd

- Number of TD's before cleaning probe tips
- Total # of cleaning events until reaching end-of-Life-Time
- Probing process capability (Cpk)
- Duration of Preventative Maintenance (PM) or repair
- Allowed increase in Contact Resistance (CRes) between cleanings
- Use of static cleaning cycle versus CRes data driven cleaning
- Retest rate to resolve test data failures at disposition step
- Mean Time to Repair (MTTR) damaged probing solution
- Percentage of reusable parts when rebuilding probing solution

Cost of Ownership (COO) & Score Card

Probing Solution Supply Chain Block Diagram Flow



Key:

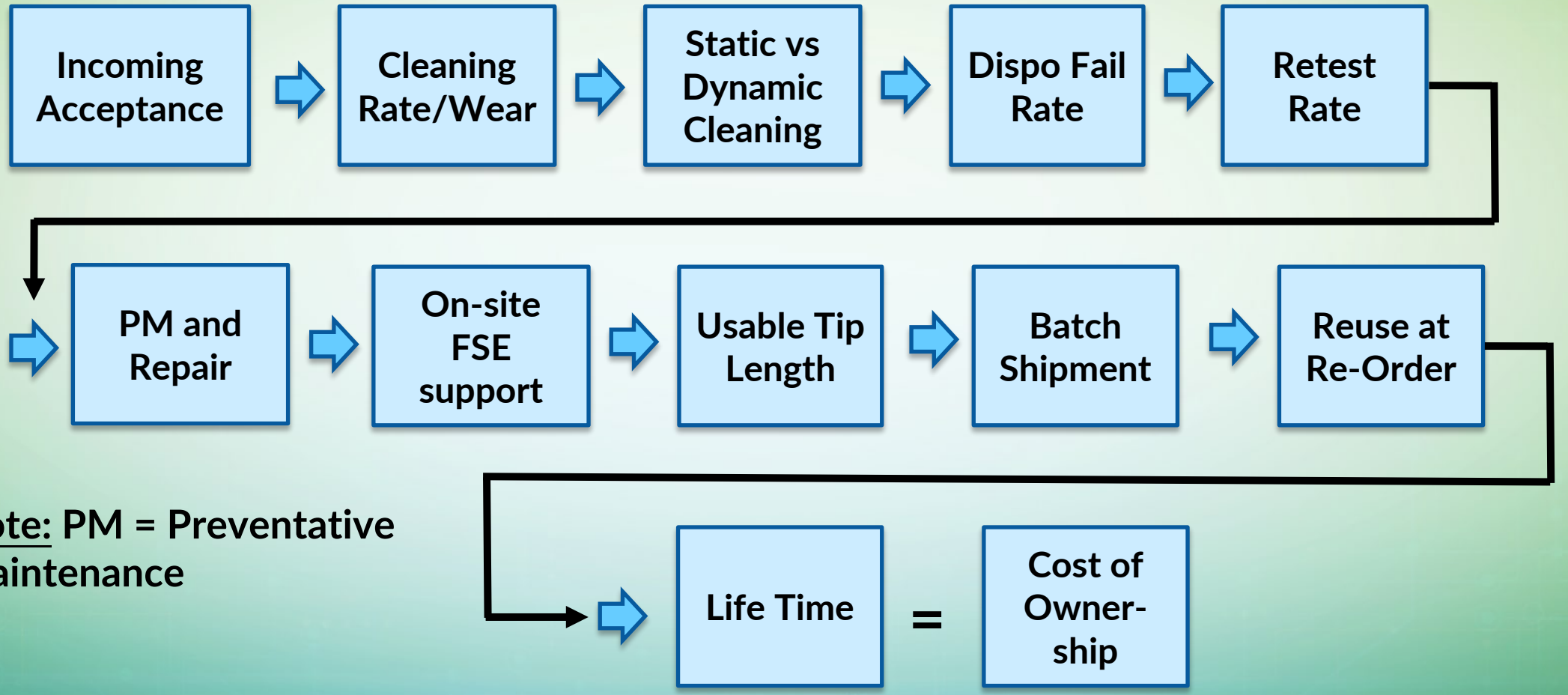
- Incoming
- Outgoing

Take Away: Customer must understand their flow

Repair Center
- In Country
- Regional
- Across Globe

Cost of Ownership (COO) & Score Card

What are the test operational blocks which impact COO?



Note: PM = Preventative Maintenance

Cost of Ownership (COO) & Score Card

COO Snapshot of impact on Test Operation

- Incoming Acceptance: 92% vs 98% means less probing units available
- Cleaning Rate/Wear: Too much cleaning means shorter Life-Time (LT)
- Static vs Dynamic Cleaning: Static cleaning typically means shorter LT
- Dispo Fail Rate: Requires DUT disposition evaluation, delays revenue
- Retest Rate: Delays current weeks' output revenue
- PM and Repair: Requires labor, disrupts test operation
- On-site FSE support: Annual service contract adds cost
- Usable Tip Length: Longer probe tip length means longer LT
- Batch Shipment: Increased batch size slows down repair/rework loop
- Reuse at Re-Order: Discarding majority of probing solution increases COO
- Life-Time: Many factors go into LT calculation including test data stability

Note:
DUT = Device Under Test

Cost of Ownership (COO) & Score Card

What drives items up your COO?

Labor: Performing inspections, resolving test failures, reintroduction of retest, PM's / repairs and visual inspection of failing product

Data Integrity: Halts test operation for statistical process control failures, product / probing solution alignment failures and equipment issues

Cleaning: Stops testing, adds to run time, lowers probing solution LT, consumes abrasive material and modulates data signal

Tester time: Retest delays incoming product from being tested, consumes test utilization and builds queue at test operation

Logistics/ Delayed Revenue : Causes extra work across all operations groups and lowers product revenue for the week

Shorter Life-Time: Means buying more probing solution units, running higher level of inventory, more stress on supply chain and increases risk of running out of inventory

Cost of Ownership (COO) & Score Card

Supply Chain and Materials

1) Raw materials
    a) Global concern for suppliers & customers
2) Board connectors
    a) Shortages are a problem
3) Electrical components
    a) High run rates, so not a concern
4) Printed Circuit Boards (PCB's)
    a) Most producers are in Asia, global concern
5) Probe needles
    a) High demand item
6) Availability of metals like Palladium
    a) Major concern for everyone across globe

Cost of Ownership (COO) & Score Card

Operational Costs

1) Incoming acceptance pass rate
    a) Delays introduction of probing solution
2) Time required to perform probe clean
    a) Periodic cleaning increases total test time
3) Preventative Maintenance (PM) labor
    a) Based on burden rate of test operation
4) Repair cost to fix damaged probing solution
    a) Function of probing solution complexity
5) Product loss due to probing damage
    a) Inspect bond pads & product looking for issues
6) Life-Time Touchdown (TD) count of probe needles
    a) Function of cleaning rate and probe profile

Cost of Ownership (COO) & Score Card

Measurement Performance

1) Safe working distance from DUT surface
    a) Critical for maximizing product revenue
2) Contact Resistance (CRes) stability
    a) Important to data integrity and confidence level
3) Current Carrying Capability (CCC)
    a) Depends upon power requirement of DUT
4) Probing process Cpk value
    a) Having process margin is critical for obtaining high Cpk
5) Probe attribute changes over LT like scrub length, usable tip length, probe tip area, Cpk and gram force / sq-um
    a) Are issues for tapered and trapezoid shaped probes
6) Signal coupling to DUT
    a) Function of probe head body proximity to DUT surface

Cost of Ownership (COO) & Score Card

DUT Operations Impact

1) Failure rate of pre-flight tests of probing solution
    a) Health check of both tester and probing solution
2) Probe check row failure rate (if present)
    a) Independent verification of contact resistance
3) Probe needle alignment success rate
    a) Manual assist halts test operations / lowers output
4) Amount of debris caused by probing solution
    a) Can cause increase in visual defect rate
5) Failure rate calculated at test disposition
    a) Must separate test operation vs product fab induced issues
6) DUT retest rate due to mis-probing by test operation
    a) Generates some percentage of product retest

Cost of Ownership (COO) & Score Card

Repair Center & Probing Solution Reuse

1) Proximity of repair center to customer site
    a) Greater distance adds days to cycle time
2) Repair center maximum monthly volume
    a) As DUT volumes increase so does repairs/rebuilds
3) Minimal batch size to run probing solution repair(s)
    a) Need to understand supplier's workload
4) Reuse percentage of probing solution at rebuild
    a) Lower reuse % means higher COO at rebuild
5) Availability of spare parts and probe needles
    a) Again, supply chain limitations will cause delays
6) Cost of on-site Field Service Engineer (FSE)
    a) Extra cost for running test operation

Cost of Ownership (COO) & Score Card

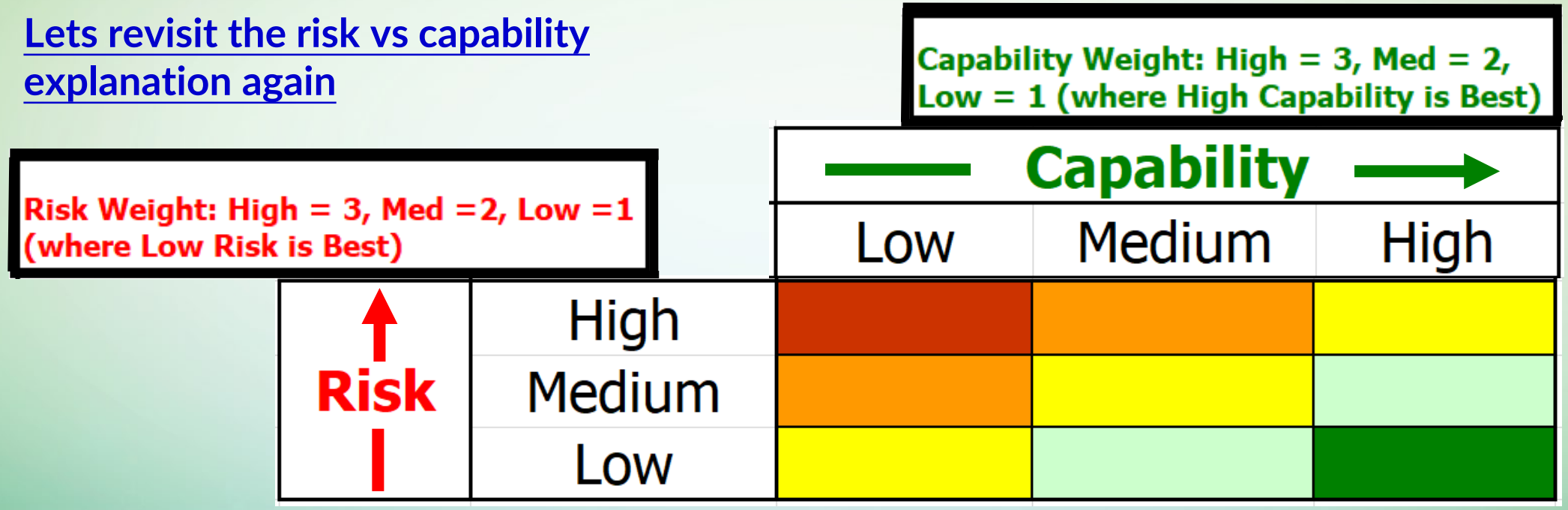
Commercial Concerns

1) Cycle time to and from repair center
    a) Longer duration increases volume of units req'd
2) LT durations within the supply chain
    a) # of outs/wk depends on receiving probing solution
3) Supplier fabrication redundancy across the globe
    a) Ensure uninterrupted goods reach customer site
4) Shortages of critical raw materials
    a) Explore alternative sources / multi-year contracts
5) Delays in goods being shipped / delivered
    a) Need to steer clear of resource limited carriers
6) Escalating cost of goods due to inflation
    a) Mostly unavoidable, and could get worse

Cost of Ownership (COO) & Score Card

To achieve the COO goal, we applied a method of assessing risk versus the probing solution capability for the test operation

Lets revisit the risk vs capability explanation again



Take Away: The goal is to minimize risk and maximize capability

Cost of Ownership (COO) & Score Card

COO score card calculation

Supply Chain / Materials

COO Identification Parameter	Current Supplier Risk #	Current Supplier Risk Assessment	Current Supplier Capability #	Current Capability Assessment	Candidate Supplier Risk #	Candidate Supplier Risk Assessment	Candidate Supplier Capability #	Candidate Capability Assessment
Supply Chain / Materials								
Raw Materials	3.0	Global issue	3.0	Great performance	3.0	Global issue	2.5	Performs well
Board Connectors	1.5	Regional	2.5	Performs well	1.0	In country	2.5	Performs well
Electrical Components	1.5	Regional	2.0	Meets spec	2.0	Regional	2.0	Meets spec
Printed Circuit Boards (PCB's)	3.0	Global issue	2.5	Performs well	3.0	Global issue	2.0	Meets spec
Probe Needles	2.0	Regional	2.0	Meets spec	1.0	In country	2.5	Performs well
Availability of Metals Like Palladium	3.0	Global issue	3.0	Great performance	3.0	Global issue	3.0	Great performance
Section Summary =	2.3		2.5		2.2		2.4	

<u>Take Away:</u> Global issues are causing higher risk

Cost of Ownership (COO) & Score Card

COO score card calculation

Operational Costs

COO Identification Parameter	Current Supplier Risk #	Current Supplier Risk Assessment	Current Supplier Capability #	Current Capability Assessment	Candidate Supplier Risk #	Candidate Supplier Risk Assessment	Candidate Supplier Capability #	Candidate Capability Assessment
Operational Costs								
Incoming Acceptance Pass Rate	2.5	5% fail rate	1.0	Not acceptable	0.5	1% fail rate	3.0	Excellent
Time Required to Perform Probe Clean	1.5	Acceptable	1.5	Acceptable	1.5	Acceptable	1.5	Acceptable
Preventative Maintenance Labor Cost	2.0	Ok	3.0	Small probe array	1.5	Acceptable	3.0	Small probe array
Cleaning Abrasive Replacement Cost	1.5	Acceptable	2.0	Ok	1.5	Acceptable	2.0	Ok
Repair Cost to Fix Damaged Probing Solution	1.5	Acceptable	1.0	High	1.5	Acceptable	2.0	Good
Wafer Loss Due to Probe Damage	1.0	Low	1.5	Typical	1.0	Low	1.5	Typical
Life-Time TD Count of Probe Needles	2.5	Above Average	2.0	Average	1.0	Great	3.0	Outstanding
Field Service Engineer (FSE) Support	2.0	Regional	3.0	Rarely needed	2.0	Regional	3.0	Rarely needed
Section Summary =	1.8		1.9		1.3		2.4	

Take Away: High operational costs increases COO

Cost of Ownership (COO) & Score Card

COO score card calculation

Measurement Performance

COO Identification Parameter	Current Supplier Risk #	Current Supplier Risk Assessment	Current Supplier Capability #	Current Capability Assessment	Candidate Supplier Risk #	Candidate Supplier Risk Assessment	Candidate Supplier Capability #	Candidate Capability Assessment
Measurement Performance								
Safe Working Distance From Wafer Surface	2.0	Cautionary	1.0	Low	1.0	Low	3.0	Outstanding
Contact Resistance (CRes) Stability	1.5	Average	1.5	Average	1.5	Average	1.5	Average
Current Carrying Capability (CCC)	1.0	Low	3.0	Outstanding	1.0	Low	3.0	Outstanding
Probing Process Cpk Value	1.0	Low	2.0	Capable	1.0	Low	3.0	Outstanding
Scrub Length Change With Wear	1.5	Average	2.0	Capable	1.5	Average	2.5	Very good
Usable Tip Length, Function of Probe Profile	2.0	Cautionary	2.0	Need to watch	2.0	Cautionary	2.5	Very good
Probe Tip Area, Function of Probe Profile	1.5	Average	2.0	Need to watch	1.5	Average	2.5	Very good
Gram Force / sq-um, Function of Probe Profile	2.0	Above normal	2.0	Typical	1.5	Average	3.0	Constant
Signal Coupling to Wafer	2.0	Above normal	2.0	Watch cap data	1.0	Low	3.0	Outstanding
Scrub Depth Impact on Contact Metal	1.0	Low	3.0	Outstanding	1.0	Low	3.0	Outstanding
Section Summary =	1.6		2.1		1.3		2.7	

Take Away: Poor performance erodes customer confidence in data

Cost of Ownership (COO) & Score Card

COO score card calculation

DUT Operations Impact

COO Identification Parameter	Current Supplier Risk #	Current Supplier Risk Assessment	Current Supplier Capability #	Current Capability Assessment	Candidate Supplier Risk #	Candidate Supplier Risk Assessment	Candidate Supplier Capability #	Candidate Capability Assessment
DUT Operations Impact								
Failure Rate of Pre-Flight Probing Tests	1.0	Low	3.0	Outstanding	1.0	Low	3.0	Outstanding
Probe Check Row Failure Rate (If Present)	1.0	Low	3.0	Outstanding	1.0	Low	3.0	Outstanding
Probe Needle Alignment Success Rate	1.5	Average	3.0	Outstanding	1.0	No issue	3.5	Exceptional
Amount of Debris Caused by Probing	1.5	Average	2.5	Good	1.0	Low	2.5	Good
Failure Rate Calculated at Test Disposition	1.5	Average	2.0	Typical	1.5	Average	2.5	Good
Wafer Retest Rate Due to Mis-Probing	1.5	Average	2.0	Typical	1.5	Average	2.5	Good
Damage to Probing Caused by Test App	1.0	Excellent	3.0	Outstanding	1.0	Excellent	3.0	Outstanding
Section Summary =	1.3		2.6		1.1		2.9	

<u>Take Away:</u> Having an outstanding probing solution lowers COO

Cost of Ownership (COO) & Score Card

COO score card calculation

Repair Center & Probing Solution Reuse

COO Identification Parameter	Current Supplier Risk #	Current Supplier Risk Assessment	Current Supplier Capability #	Current Capability Assessment	Candidate Supplier Risk #	Candidate Supplier Risk Assessment	Candidate Supplier Capability #	Candidate Capability Assessment
Repair Center & Probing Solution Reuse								
Proximity of Repair Center to Customer Site	2.0	Regional	2.0	Average	2.0	Regional	2.0	Average
Repair Center Maximum Monthly Volume	1.5	Average	2.5	Good	1.5	Average	2.5	Good
Minimal Batch Size to Run Probing Repairs	1.5	Average	2.0	Minimal = 4	1.0	Low	2.5	Minimal = 3
Reuse % of Probing Solution at Rebuild	3.0	High	2.0	Watch lead-time	1.0	Low	2.0	Watch lead-time
Availability of Spare Parts and Probe Needles	1.5	Average	2.0	Typical	1.5	Average	3.0	No issue
Cost of On-Site Field Service Engineer	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Section Summary =	1.9		2.1		1.4		2.4	

Take Away: Regional repair / high reuse rate lowers COO

Cost of Ownership (COO) & Score Card

COO score card calculation

Commercial Concerns

COO Identification Parameter	Current Supplier Risk #	Current Supplier Risk Assessment	Current Supplier Capability #	Current Capability Assessment	Candidate Supplier Risk #	Candidate Supplier Risk Assessment	Candidate Supplier Capability #	Candidate Capability Assessment
Commercial Concerns								
Cycle Time to and From Repair Center	2.0	Typical	2.0	Watch shipping	2.0	Typical	2.5	Good
Lead-Time Durations in Supply Chain	2.0	Typical	2.0	Increases COO	1.5	Good	2.5	Good
Supplier Fab Redundancy Across the Globe	1.5	Good	3.0	Outstanding	1.0	Low	3.0	Outstanding
Shortages of Critical Raw Material	1.5	Issue w/metals	2.0	Global concern	1.0	No Issues	2.0	Global concern
Delays in Goods Being Shipped / Delivered	1.5	Typical	2.0	Watch batch size	1.0	Minimal risk	2.0	Watch batch size
Escalating Cost of Goods Due to Inflation	2.0	Concern	2.0	No control	2.0	Concern	2.0	No control
Supplier Documented Disaster Relief Plan	1.0	No issue	3.0	No issue	1.0	No issue	3.0	No issue
Section Summary =	1.6		2.3		1.4		2.4	
Overall Summary =	1.72		2.22		1.42		2.55	

Take Away: Example of supplier with higher risk and less capability

Cost of Ownership (COO) & Score Card

Summary

- Score card concept is being presented here as a way to obtain the best test data & highest yield possible at the lowest cost
- COO score card goes far beyond a handful of basic parameters
- The score card looks for ways to increase throughput & lower COO
- Helps customer to assess test operation and labor utilization
- The card is intended to highlight costs, i.e., reducing waste
- Your COO is a mixture of controllable and uncontrollable elements
- Score card will help customer focus on top priorities of COO
- The supplier pendulum is swinging back to onshore manufacturing
- In closing, a risk vs capability score card is being offered to help you more accurately calculate your probing solution COO

Cost of Ownership (COO) & Score Card

Thank you

Cost of Ownership (COO) & Score Card

Q&A