AEHR TEST SYSTEMS

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Cost Versus Reliability Tradeoffs for Stacked Die

Steve Steps,
Aehr Test Systems,
ssteps@aehr.com

Agenda

- Why Burn-in?
- Wafer-Level Burn-In (WLBI) cost versus benefit case studies
  - Simple DRAM package
  - DRAM DIMM
  - Stacked Module
  - Automotive Application
- Conclusions

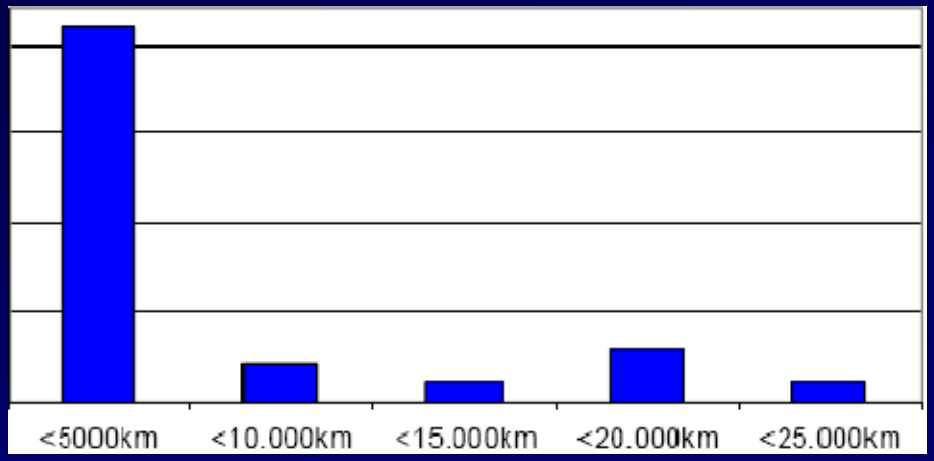
WLBI Motivation

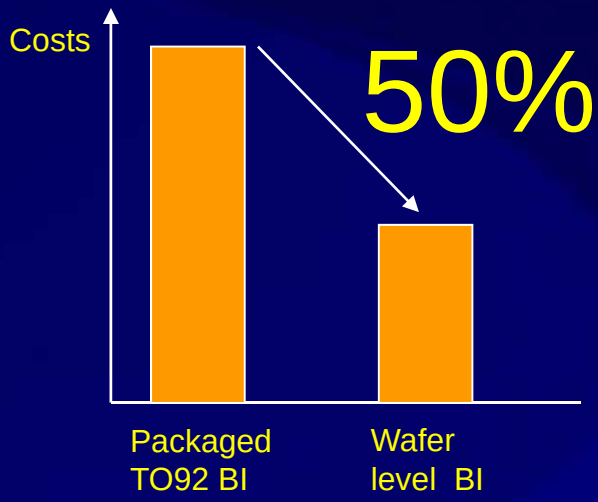
Eliminate early failures …

to improve initial quality …

by burn in on wafer level

75% of failures occur before 5000km





Minimize burn in costs…

to achieve industry best cost level…

by burn in on wafer level

From BiTS 2009: Wafer-Level Burn-In of Hall-Effect Sensors

Tradeoffs Analysis Objective

- To determine what factors affect the decision whether or not to burn-in a device
- Compare burn-in benefit versus cost across several different applications
- All scenarios assume DRAM type parts for consistency
  - Analysis applies to all types of devices

Tradeoff Assumptions

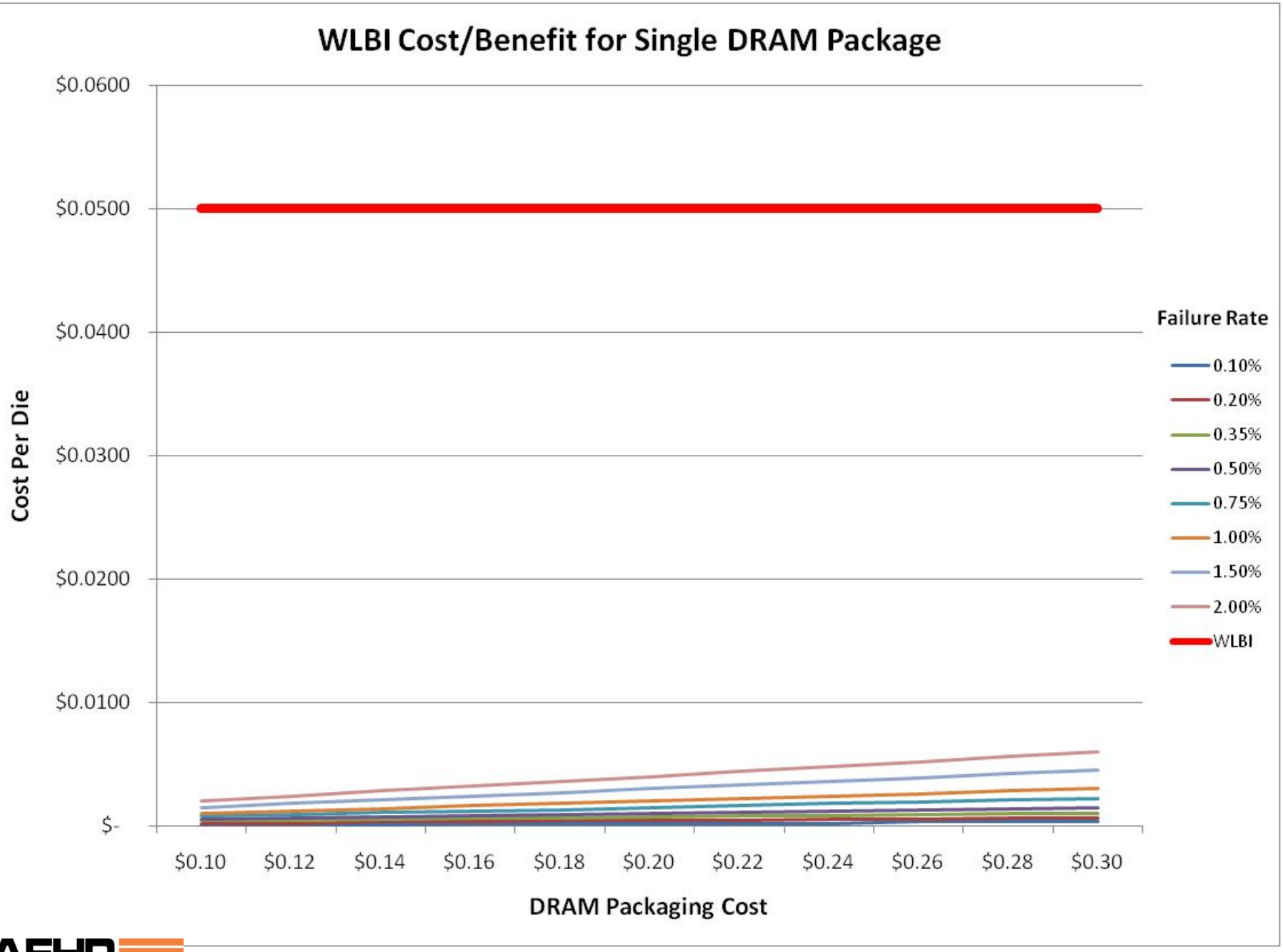
- Leading edge DRAMs estimated as 750 die per wafer and about $2 each
- Other DRAMs estimated as1500 die per wafer and about $1 each
- All failure rates are improvement due to burn-in

  = Non-Burn-In failure rate – Burn-In failure rate
- Wafer-Level Burn-in (WLBI) cost estimated as
  - 5 cents per die for leading edge DRAMs
  - 2.5 cents per die for other DRAMs

Simple DRAM Scenario

- Single, leading edge DRAM die
- Single die, FBGA package
- Model Cost per Die versus
  - WLBI reliability improvement
  - Packaging cost
- Analysis ignores implications of failure

Source: Digikey

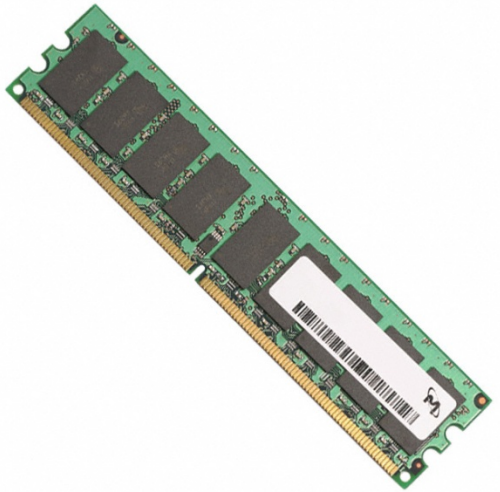

WLBI Cost/Benefit for Single DRAM Package
$0.0600
$0.0500
$0.0400
$0.0300
$0.0200
$0.0100
$-
Cost Per Die
$0.10
$0.12
$0.14
$0.16
$0.18
$0.20
$0.22
$0.24
$0.26
$0.28
$0.30
DRAM Packaging Cost
Failure Rate
0.10%
0.20%
0.35%
0.50%
0.75%
1.00%
1.50%
2.00%
WLBI

Simple DRAM Observations

- Failure cost savings are quite small
  - Failing die would have been thrown away
  - Cost savings is in avoiding packaging early failure die
  - WLBI would cost much more than savings
- Other implications of failure would be MUCH higher, but ignored in this analysis
  - Downstream product failures
  - Bad customer relations

DRAM DIMM Scenario

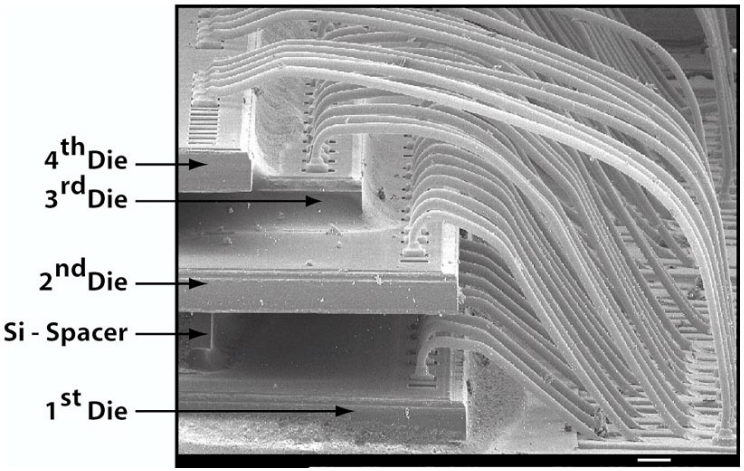
- DRAM DIMM with multiple die
  - Assumes no post-assembly repair
  - Failure of a die causes loss of DIMM
  - WLBI cost estimated as 5 cents/die
- Model Cost per Die versus
  - WLBI reliability improvement
  - Number of die per DIMM

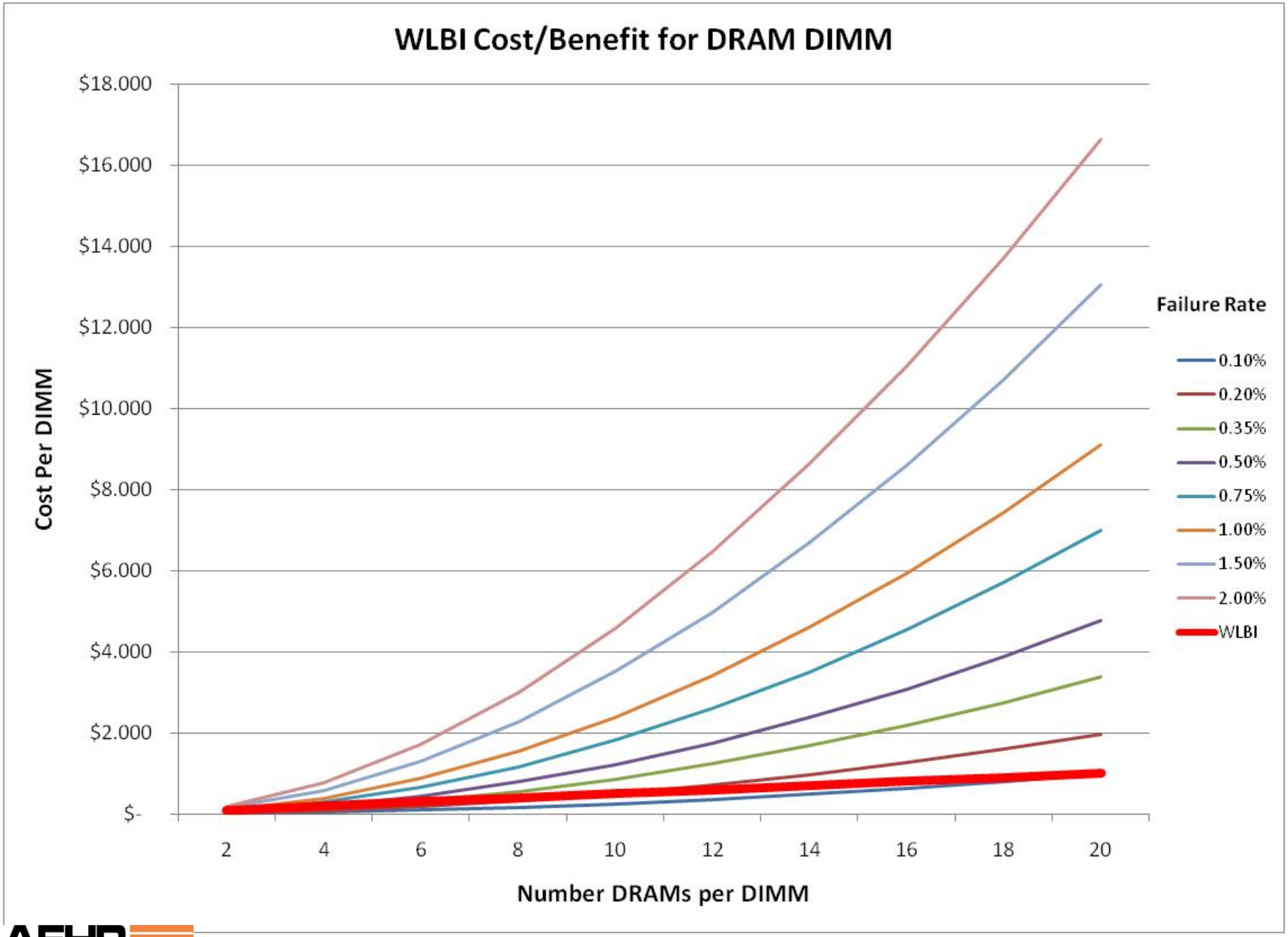


Source: Digikey

Cost of Failure

- Module failure rate = *f*(die count)
- Module cost = *f*(die count)
- Failure cost =
  (Module failure rate) * (Module cost)
- Failure cost = *f*(die count^2)



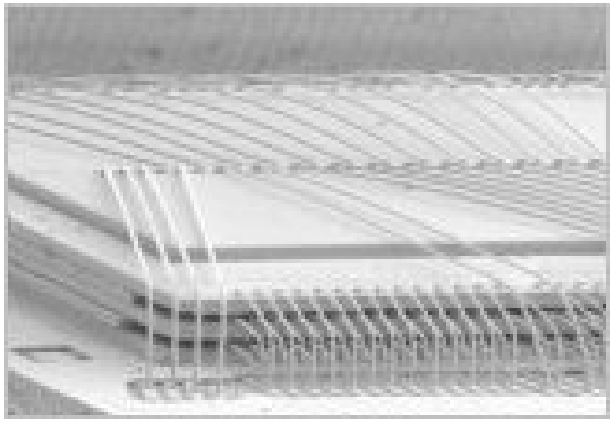

WLBI Cost/Benefit for DRAM DIMM
$18.000
$16.000
$14.000
$12.000
$10.000
$8.000
$6.000
$4.000
$2.000
$-
Cost Per DIMM
2
4
6
8
10
12
14
16
18
20
Number DRAMs per DIMM
Failure Rate
0.10%
0.20%
0.35%
0.50%
0.75%
1.00%
1.50%
2.00%
WLBI

DRAM DIMM Observations

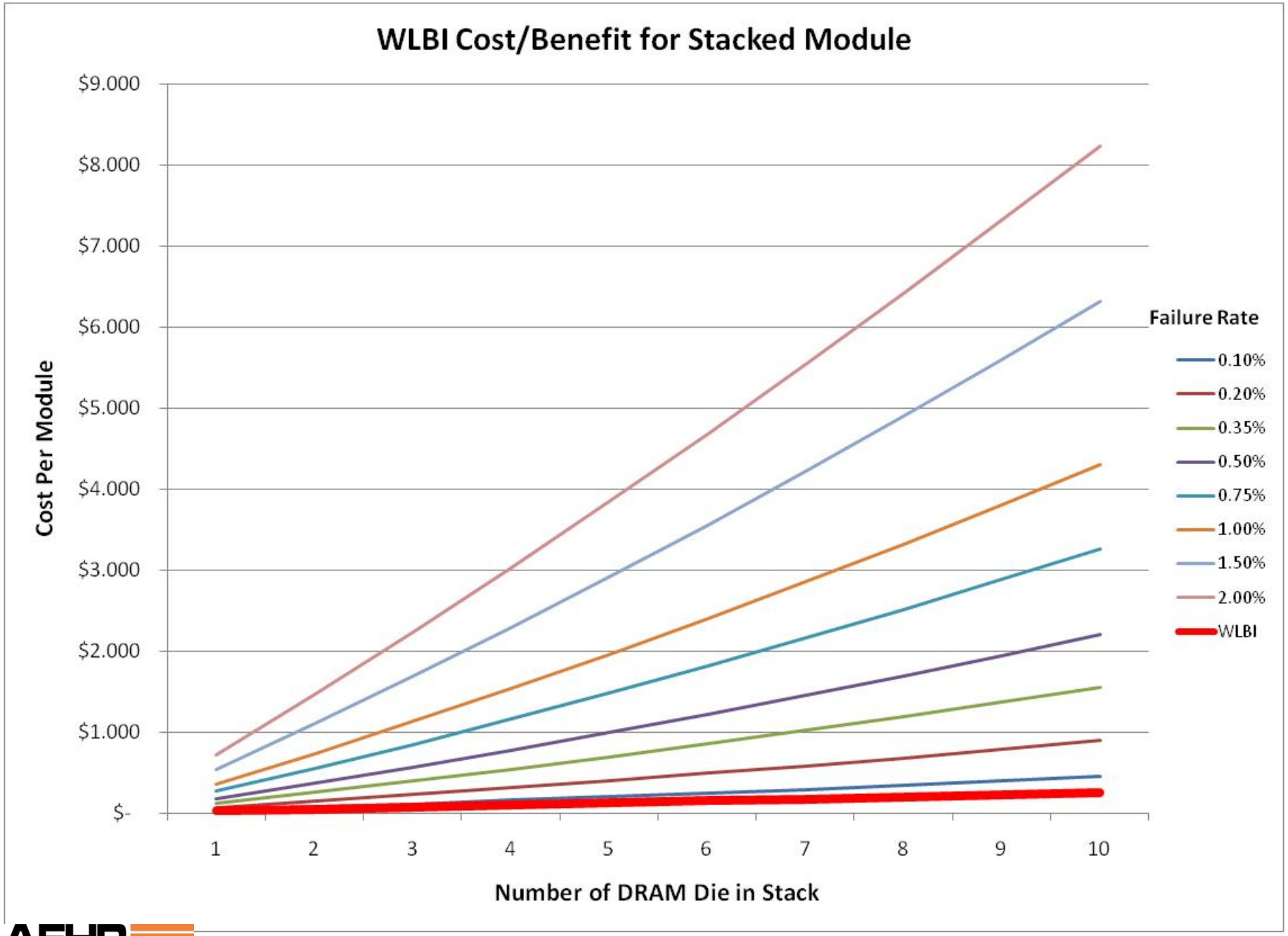
- Failure costs of DRAM DIMM are much higher due to:
  - Any die failure causes good die to be thrown away, "One bad apple spoils the barrel"
  - Failure cost is related to the square of die count
- WLBI very cost effective in most cases
  - WLBI cost linear with die count
  - More cost-effective as die count increases

Stacked Die Scenario

- Stacked package with:
  - $20 microcontroller chip
  - 2 flash die @ $5 each
  - 1 to 10 simple DRAMs @ $1 each
  - $5 packaging cost
- Model Cost per Die versus
  - DRAM WLBI reliability improvement
  - Number of DRAMs in the stack
- Note: only DRAM failures considered



Source: STATS ChipPAC

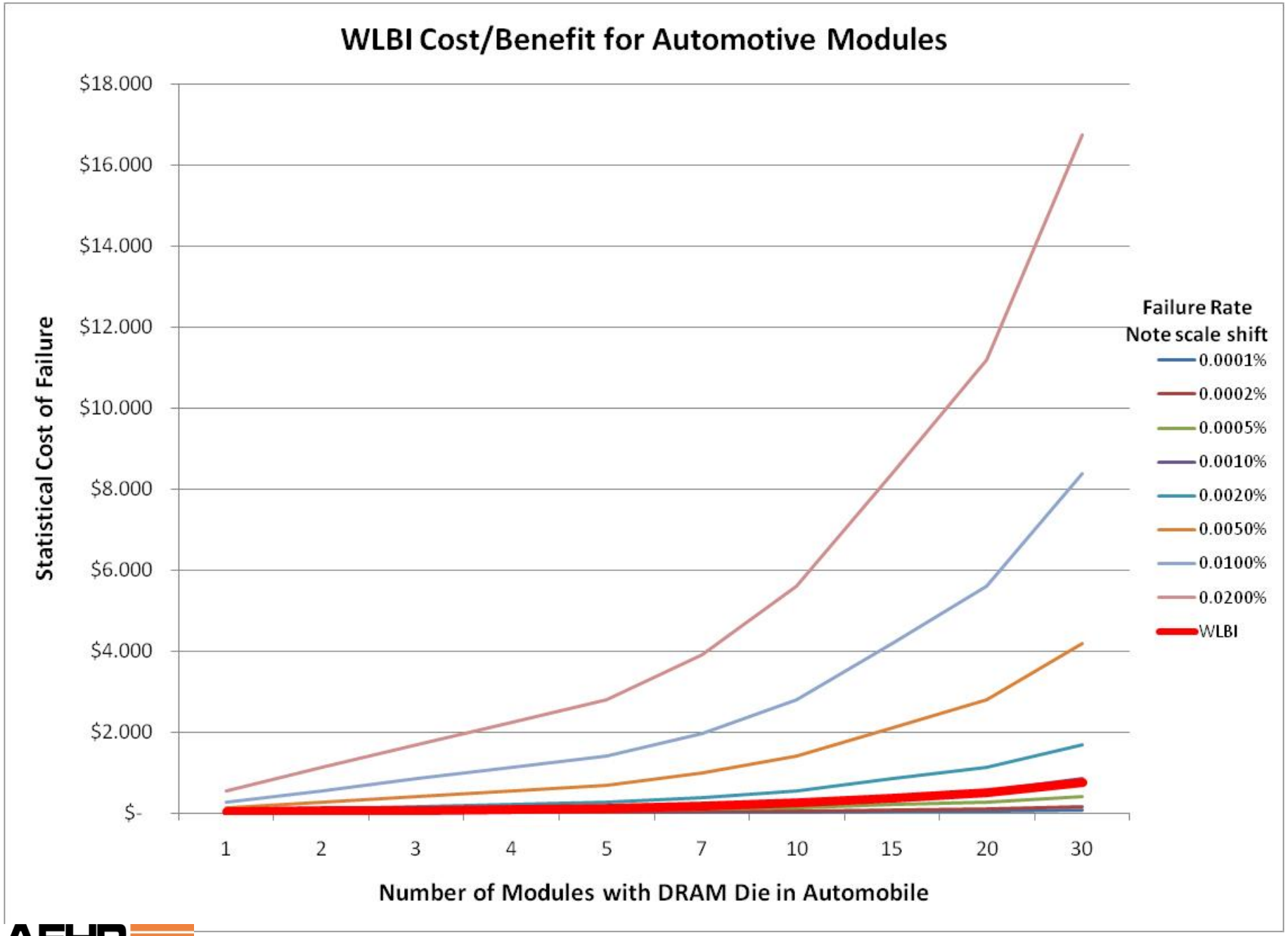

WLBI Cost/Benefit for Stacked Module
$9.000
$8.000
$7.000
$6.000
$5.000
$4.000
$3.000
$2.000
$1.000
$-
Cost Per Module
1
2
3
4
5
6
7
8
9
10
Number of DRAM Die in Stack
Failure Rate
0.10%
0.20%
0.35%
0.50%
0.75%
1.00%
1.50%
2.00%
WLBI

Stacked Module Observations

- Failure costs of stacked module start out much higher due to:
  - Any DRAM die failure causes entire module (including other die) to be lost
- Failure cost is more linear for same reason
- WLBI can be very cost effective
  - Even if DRAMs are a very small fraction of module cost

Automotive Module Scenario

- Simple modules with small DRAM die
- Cost of failure to manufacturer estimated as:
  - $300 warranty repair bill for parts & labor
  - 10% decrease in customer likelihood to buy same brand again
  - Car price for model: $25,000
  - $2800 total cost of failure
- Note major shift in assumed DRAM reliability!


WLBI Cost/Benefit for Automotive Modules
$18.000
$16.000
$14.000
$12.000
$10.000
$8.000
$6.000
$4.000
$2.000
$-
Statistical Cost of Failure
1
2
3
4
5
7
10
15
20
30
Number of Modules with DRAM Die in Automobile
Failure Rate
Note scale shift
0.0001%
0.0002%
0.0005%
0.0010%
0.0020%
0.0050%
0.0100%
0.0200%
WLBI

Automotive Observations

- The end application can highly affect the demand for highly reliable KGD
- Even extremely reliable modules may be insufficient
  - Even single digit PPM may be too high
- WLBI very cost effective in most cases
  - Even if DRAMs are a very small fraction of module cost

Conclusions

- If any of the following are true, then WLBI is likely to be very cost-effective:
  - Many die in a non-repairable assembly
  - Module contains high valued die
  - If the application has a very high cost of failure
- WLBI effectiveness is typically not dependent upon the die's cost