Example CoO Technology Analysis

This presentation was taken from an actual cost of ownership model and analysis we did for a supplier of imaging technology (around 2012). The presentation was tailored based on some specific requests and issues identified by the customer, but is representative of the type of analysis the models enable us to perform (capital sensitivity, what-if's, yield thresholds, etc.)

The names and specific values have been modified to protect confidential data.

SavanSys

Agenda

- **Assumptions**
- **Analysis and Key Observations**
  - Tech Supplier 1 vs. Traditional (Aligner and Stepper)
  - Tech Supplier 1 vs. other LDI
- **Other**
  - Technical questions
  - Risks
  - Opportunities
- **The term "Board" and "Package" are used interchangeably in this presentation**

Process Assumptions

	Tech Supplier 1 LDI	LDI 2 - Standard	LDI 2 - Special	LDI 3 - Standard	Aligner	Stepper
Equipment Cost (kUSD)	$2500.00	$1,250.00	$1,250.00	$1,100.00	$600.00	$2,000.00
Throughput (s/panel side)	28	60	20	53.5	30-40	60
Annual Service Contract (%)	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
% Up Time (Fully Utilized)	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
% Utilization (Fully Utilized)	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
% Scrap Panels in Alignment	1.0%	1.0%	1.0%	1.0%	2.0%-3.0%	1.0%
Per Mask Cost	$0.00	$0.00	$0.00	$0.00	$3,500.00	$3,500.00
# Masks Required (Per Side)	0	0	0	0	4	1
Mask Cleaning Frequency (Panels)	0	0	0	0	10-30	10-30
Mask Set Lifetime (Panels)	0	0	0	0	5000	5000
Photoresist Cost ($/sq ft)	$0.10 - $0.13	$0.10 - $0.13	$0.50	$0.10 - $0.13	$0.10 - $0.13	$0.10 - $0.13

Green = Second Source Verified (Ranges provided for completeness)

Yellow = Based on SavanSys experience

Blue = Based on Tech Supplier 1 values

- **These are the assumptions generally used when generating the results for each process**

Design Assumptions

Scenarios:	Advanced BGA	Commodity BGA	Advanced CSP	Commodity CSP	Consumer Non Hand Held	Hand Held Mobile Device
Package Length (mm)	31.00	31.00	10.00	10.00	152.00	100.00
Package Width (mm)	31.00	31.00	10.00	10.00	152.00	50.00
Substrate Stucture	4-2-4	0-4-0	2-2-2	0-2-0	0-4-0	3-4-3
Package IO Count	900	900	90	90	2000	2000
Panel Length (mm)	406.40	406.40	406.40	406.40	457.20	457.20
Panel Width (mm)	457.20	457.20	457.20	457.20	609.60	609.60
Processing Cost Adder	$1.15	$0.10	$0.15	$0.00	$0.00	$0.00
Shipping Yield	75%	95%	75%	95%	97%	75%
Typical Panel Costs	$600+	$150-$175	$500	$85-$125	~$100	$400++
Applications	Mobile Phone, high end servers	PC, Automotive	Mobile phone	Consumer Electronics (Networking, PC, etc)	PC, Automotive	Mobile phone (this design based on iPhone)

- **These are the assumptions used for each different design scenario**
  - The most significant differences between each scenario are: Body Size, Final Yield, and Target panel cost
- **How the model handles yield**
  - "Shipping Yield" includes all yield loss through shipping
  - "% Scrap Panels" affects the material cost of the core material but does not include any additional package yield loss. Our assumption is the material is identified as bad before any significant processing.

Imaging Impact

- **The direct costs of imaging are low, between 1%-3% depending on design and imaging technique**
- **However, the costs of imaging + scrap is much more significant (5% - 25%)**

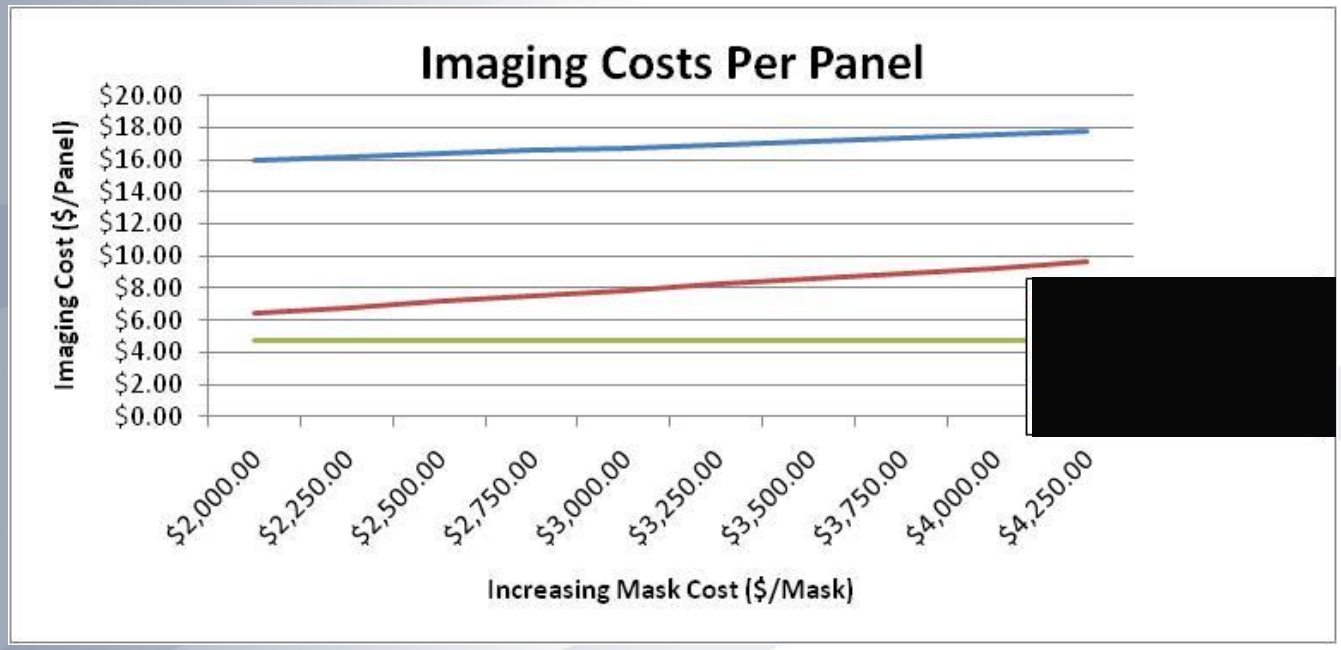
	Scenarios:	Advanced BGA	Commodity BGA	Advanced CSP	Commodity CSP	Consumer Non Hand Held	Hand Held Mobile Device
Tech Supplier 1	Total Cost (Board)	$4.76	$1.13	$0.53	$0.11	$18.14	$9.16
	Imaging (% Of Total)	*0.86%*	*0.73%*	*0.65%*	*1.04%*	*1.09%*	*1.18%*
	Scrap (% Of Total)	*20.83%*	*4.17%*	*20.84%*	*4.14%*	*2.50%*	*20.83%*
Stepper	Total Cost (Board)	$5.15	$1.20	$0.56	$0.12	$19.35	$9.99
	Imaging (% Of Total)	*3.01%*	*2.59%*	*2.28%*	*3.67%*	*3.61%*	*3.81%*
	Scrap (% Of Total)	*23.33%*	*6.67%*	*23.34%*	*6.71%*	*5.00%*	*23.33%*
Aligner	Total Cost (Board)	$5.14	$1.22	$0.57	$0.12	$19.58	$9.93
	Imaging (% Of Total)	*1.31%*	*2.01%*	*1.11%*	*2.86%*	*2.82%*	*1.80%*
	Scrap (% Of Total)	*25.00%*	*8.33%*	*25.00%*	*8.33%*	*6.67%*	*25.00%*

- **We believe a significant portion of yield loss is related to the imaging process**
  - This means demonstrable yield differences represent a large opportunity

Analysis Highlights: LDI vs. Traditional

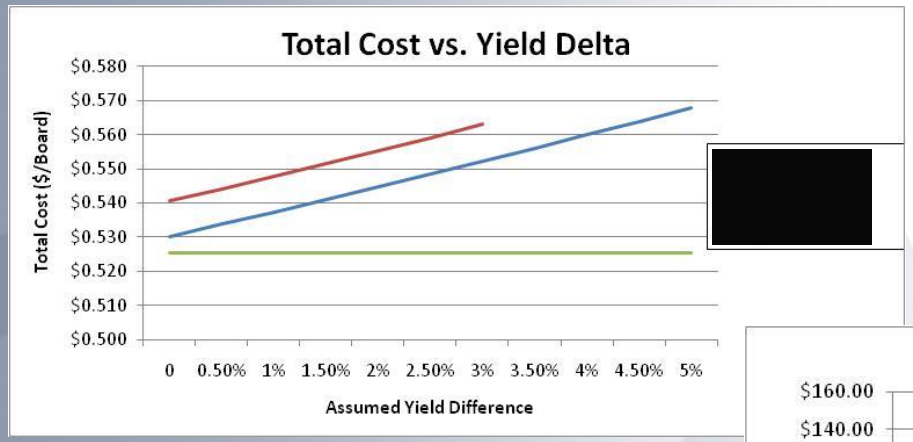
- **We compared Tech Supplier 1 vs. Stepper and Aligner**
  - Most significant cost drivers are the # and cost of each mask
  - The difference in final package yield is the biggest opportunity
  - The mask lifetime is only significant if the lifetime is less than about 3,000 panels. After this point the mask is mostly depreciated.
- **LDI has a cost advantage**
  - When panel is expensive (advanced applications)
  - Fundamental process is less expensive
- **Traditional is more competitive**
  - When packages/boards are small (additional imaging costs are spread over more packages).
  - When current infrastructure already supports
    - *Additional costs and complexity of dealing with masks are already entrenched in process so potential "savings" aren't necessarily included in the mind of the supplier*

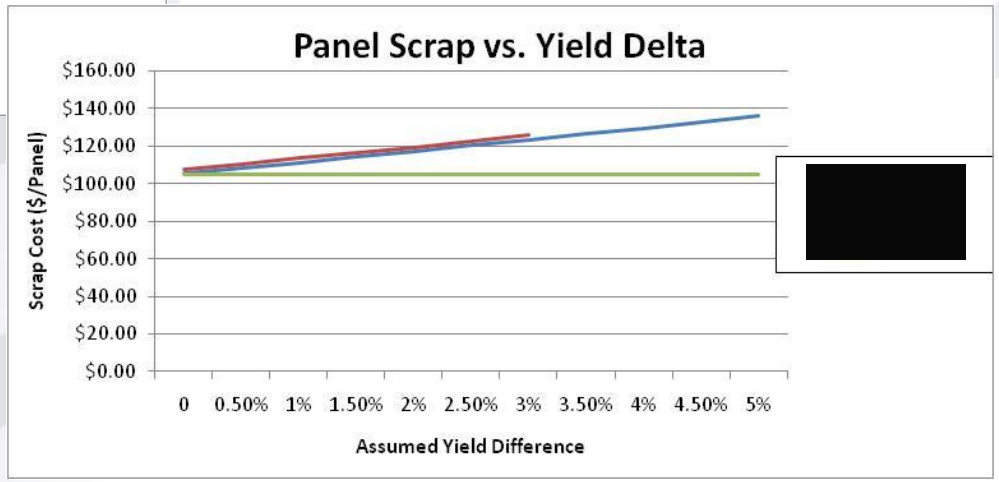
Mask Cost Sensitivity



- **This assumes**
  - 139 min and $1.5M to generate artwork
  - 10 min and $75,000 equip in handling costs (clean room and storage expenses)
  - Mask costs as stated in chart

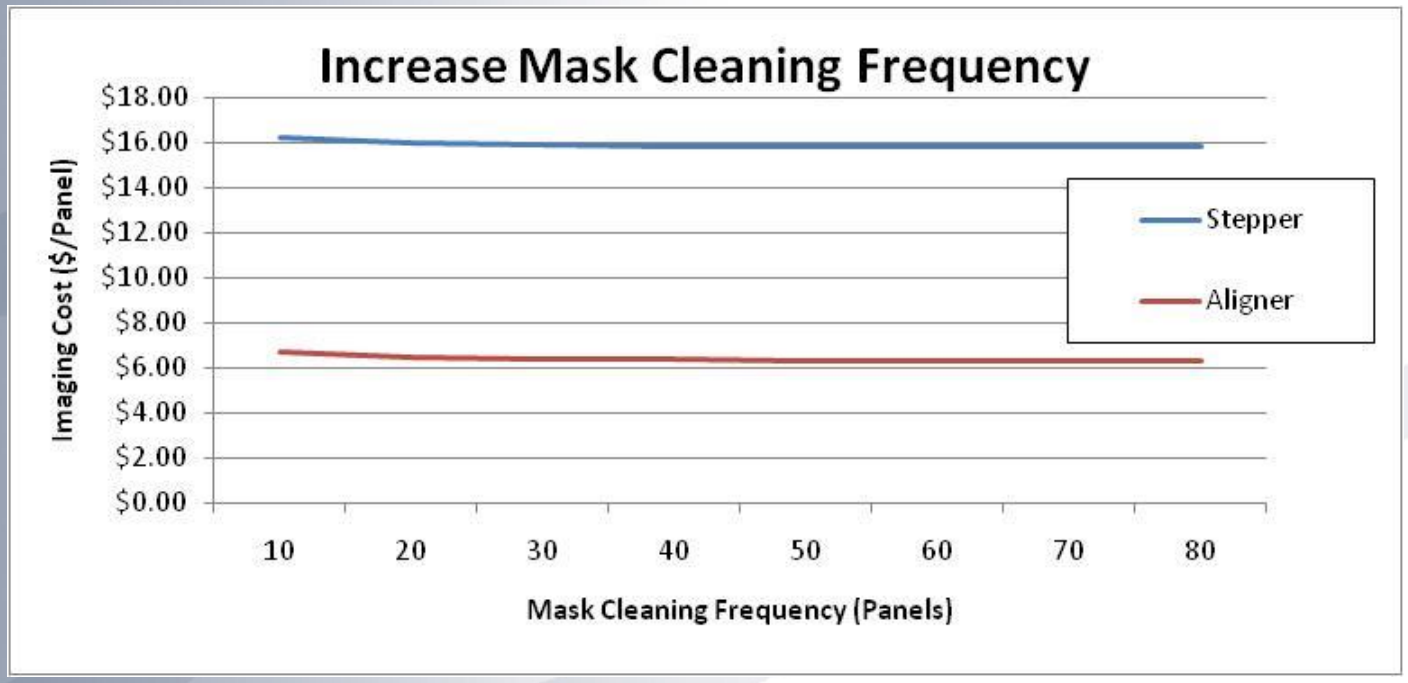
Cost vs. Yield Delta Sensitivity





- **Assumed Stepper yields do not differ more than 3%**
- **Saving an additional 1-3% of an expensive panel can be significant**

Mask Cleaning



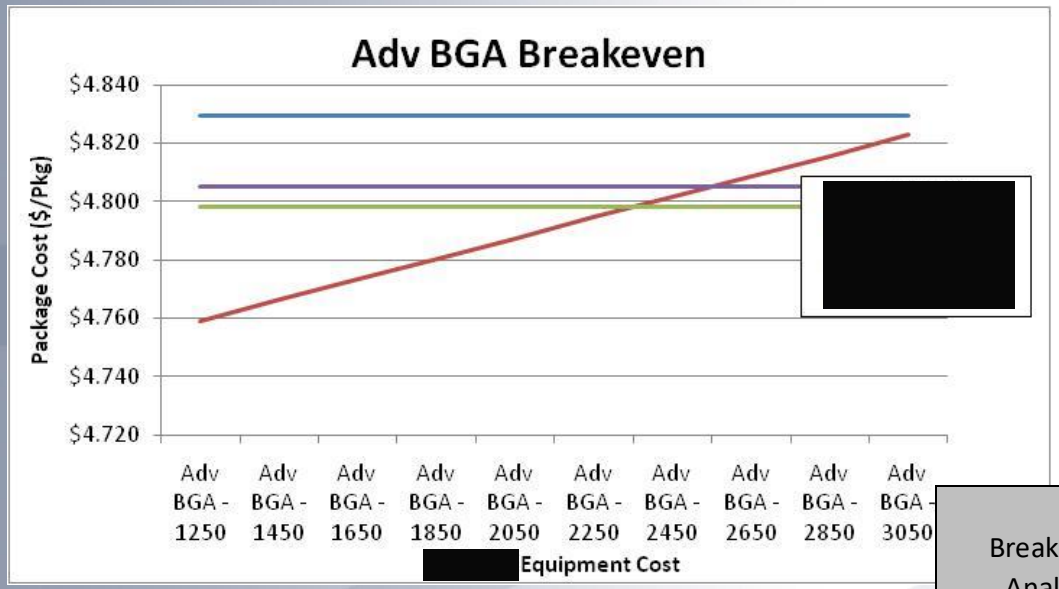
- **Mask Cleaning frequency has little impact on cost**
  - Assumes 5 min to clean the mask every 20 panels
  - 200K Equipment

Analysis Highlights: Tech Supplier 1 vs. Other LDI

- **We compared Tech Supplier 1 vs. LDI 2 and LDI 3**
  - Throughput is the biggest driver
    - *Important to try and confirm real-world throughput's currently being experienced for all technologies*
  - LDI 2 Special may not be suited to larger panel sizes
    - *The high photo-resist cost increases proportionally with panel size*
    - *Throughput for the other technologies probably scales slower*

- **Imaging costs are relatively small. It's hard to build a compelling reason based only on cost to choose one LDI technology**
  - If throughput assumptions correct, Tech Supplier 1 does have an advantage
  - Other reasons may be maintenance, support, flexibility, or other technical features

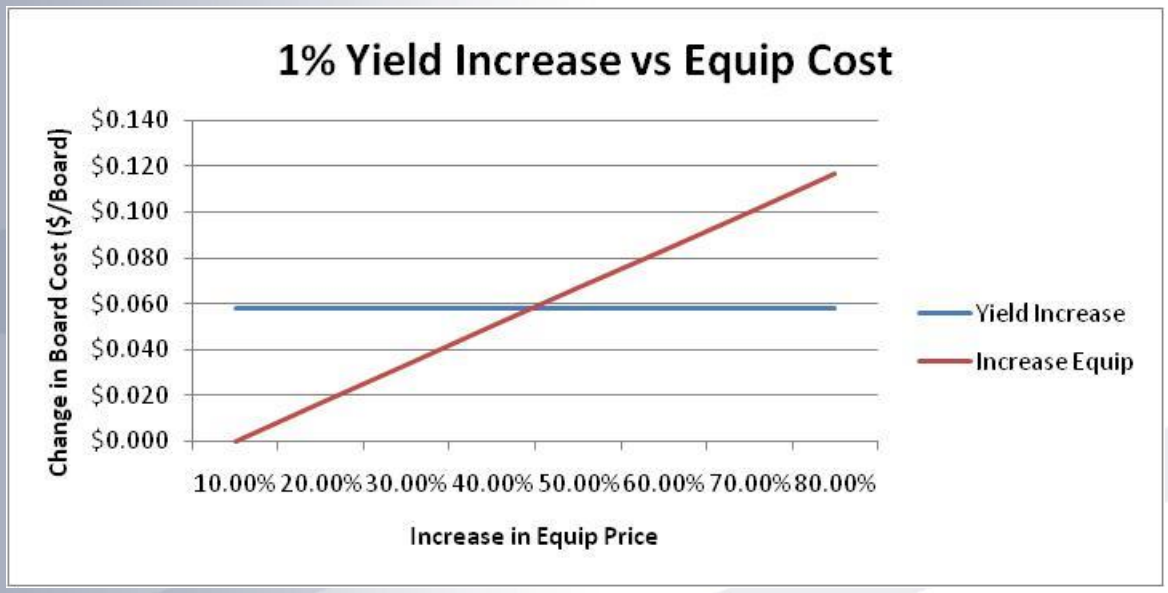
Breakeven Analysis



Breakeven Analysis	Competition Equip at	Breakeven Capital Cost (Pacakges)	Breakeven Capital Cost (Boards)
[redacted]	$1,250.00	$3,150.00	$3,250.00
	$1,250.00	$2,350.00	$3,050.00
	$1,100.00	$2,550.00	$2,550.00

- **Because imaging is relatively small part of the package cost, the capital cost can vary a lot without changing the total.**

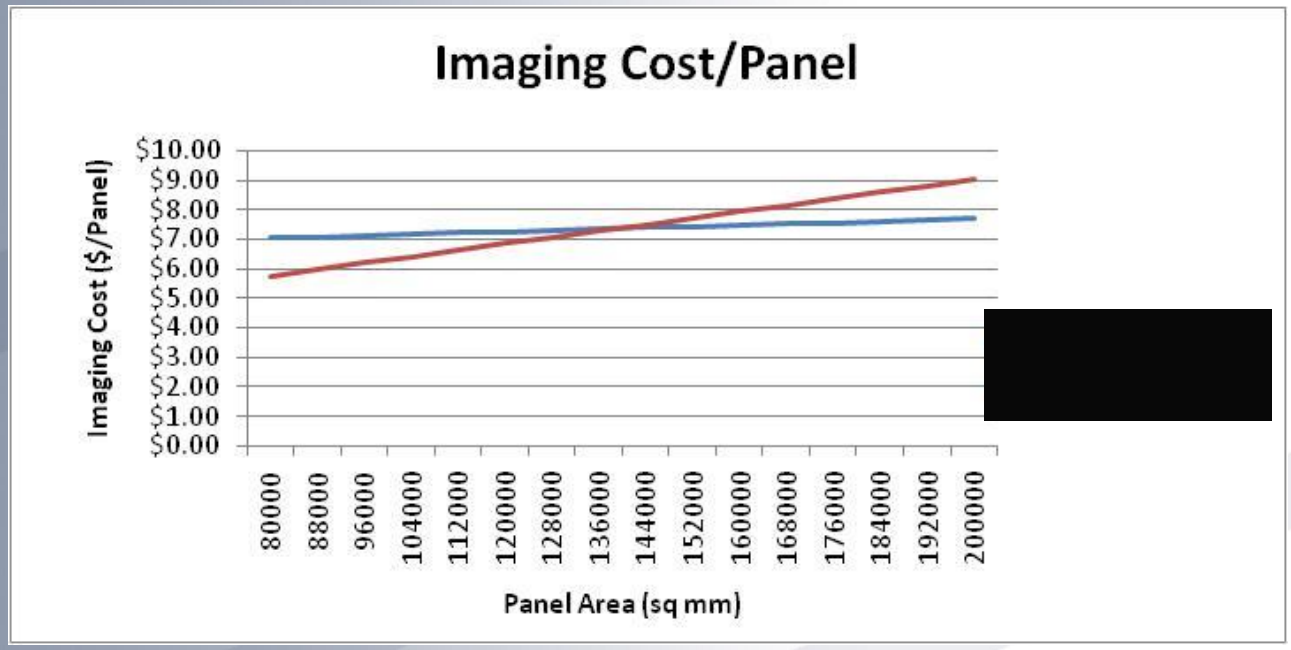
% Change in Yield



- **A 1% improvement in yield is equivalent to an increase of 45% in equipment price**
  - Based on Mobile Board design and a baseline of $2,000K Tech Supplier 1 Equipment price.

- **Commodity designs will have a slightly smaller opportunity for equipment cost (because the designs are cheaper and tend to already be higher yield, a 1% yield increase is worth less)**

LDI 2 Special Photoresist



* Assumes 60 cent/sq ft for special photoresist

* Assumes constant panel throughput on both machines

- **High photo-resist cost scales with area**
  - Unless panel throughput slows proportionally, LDI 2 Special will have a cost disadvantage at larger panels
- **If Tech Supplier 1 is at $2M capital, then LDI 2 Special photoresist less than $0.40/sq ft is more cost effective**
  - For advanced BGA scenario. This changes somewhat with different panel sizes.

Outstanding Questions

- **How much of typical yield loss is contributed by the imaging process?**
  - Update 8-28: We have seen other evidence that at least 50% of the yield loss associated with normal panel processing is associated with the imaging process. This is consistent with the assumptions already used in our analysis.
- **How many masks are generally needed for Aligner and Steppers?**
- **How does Tech Supplier 1 (and other equipment) throughput change based on panel size?**
- **Trends**
  - Thin Substrates
  - Wafer level packaging (eWLB)